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THE AMERICAN JOURNAL OF SCIENCE AND ARTS.

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THIRD SERIES.

VOL. XVIII.—[WHOLE NUMBER, CXVIII.]

Nos. 103—108.

JULY TO DECEMBER, 1879.

WITH THREE PLATES.

NEW HAVEN: J. D. & E. S. DANA.
1879.

253577

TUTTLE, MOREHOUSE & TAYLOR, PRINTERS, 371 STATE STREET.

CONTENTS OF VOLUME XVIII.

NUMBER CIII.

SCIENTIFIC INTELLIGENCE.

NUMBER CIV.

SCIENTIFIC INTELLIGENCE.

NUMBER CV.

SCIENTIFIC INTELLIGENCE.

NTMBER CVI.

SCIENTIFIC INTELLIGENCE.

NUMBER CVII.

SCIENTIFIC INTELLIGENCE.

NUMBER CVIII.

SCIENTIFIC INTELLIGENCE.

118-1879

THE

AMERICAN

JOURNAL OF SCIENCE AND ARTS.

[THIRD SERIES.]

ART. I.—*Contributions to Meteorology, being results derived from an examination of the Observations of the United States Signal Service and from other sources;* by ELIAS LOOMIS, Professor of Natural Philosophy in Yale College. Eleventh paper. With plates I and II.

[Read before the National Academy of Sciences, Washington, April 15, 1879.]

The Winds on Mt. Washington compared with the winds near the level of the sea.

IN my last Article I gave some reasons for believing that areas of low pressure sometimes result from a circulation of the surface winds which does not extend to the height of 6,000 feet. In order to investigate this subject more fully, I selected from the published volumes of the Signal Service observations all those cases in which the direction of the wind on Mt. Washington differed at least 90° from that at each of the stations, Burlington, Boston, and Portland, Me. The number of these cases was 507. Three-fifths of these cases occurred when the wind on Mt. Washington was from the west or northwest, and more than four-fifths of them occurred when the wind on Mt. Washington was from one of the points N., N.W., W. or S.W.; and at the same time the wind at the neighboring surface stations was generally from one of the points S., S.E., E. or N.E. As this Table, if accompanied with the details necessary to render it intelligible, is too large for publication, I have adopted a different standard of selection, and have taken all those cases in which the barometer at Portland, Me., fell as low as 29·6 inches. This list has already been given in my tenth paper, page 9, except that I have added the cases found in the volumes of observations since published for January, February and

Table I.— ***Winds on Mt. Washington compared with the surface w***

	1872.						
1	Oct.	12.2 S.W. 5	12.3 W. 30	13.1 S.W. 27	13.2 N.W.30	13.3 N. 59	14.1 S
		S. 4	S. 6	S. 9	S.E. 12	N.E. 8	*N
2		25.3 N.W.15	26.1 S.E. 24	26.2 S.W. 29	26.3 S.W. 18	27.1 N.E. 4	27.2 N
		E. 2	N.E. 6	N.E. 5	N.E. 7	*N. 8	N
3	Nov.	6.1 N.W.20	6.2 N.W.28	6.3 N.W.30	7.1 S.E. 4	7.2 S.W. 38	7.3 N
		S. 3	S. 9	S. 8	S.E. 3	*W. 9	W
4		11.1 calm.	11.2 W. 13	11.3 S.E. 50	12.1 S.W. 28	12.2 S.W. 65	12.3 N
		S. 2	S. 10	S. 7	S. 8	S. 8	*N
5		13.2 N.W. 5	13.3 S. 15	14.1 W. 55	14.2 S. 30	14.3 W. 32	15.1 W
		N. 4	S.E. 4	S.E. 5	S.E. 5	*W. 4	W
6		28.3 S.W. 22	29.1 N.E. 22	29.2 S.W. 35	29.3 S.W. 22	30.1 N.E. 45	30.2 S
		S. 4	S.E. 9	N.W. 9	W. 10	*W. 13	S
7	Dec.	1.3 W. 32	2.1 S.E. 25	2.2 W. 35	2.3 S. 42	3.1 S.E. 51	3.2 S
		S. 5	S. 4	S. 4	S.W. 5	*W. 13	W
		3.3 S.E. 42	4.1 W. 58			9.3 S.E. 16	10.1 W
		W. 7	W. 9			N.W.15	N
8		7.3 W. 8	8.1 S.E. 49	8.2 S.E. 54	8.3 N.W.22	9.1 calm.	9.2 S
		S. 7	S. 9	S. 8	S. 5	S. 2	*N
9		26.1 N.W.16	26.2 N.E. 2	26.3 S. 5	27.1 calm.	27.2 N.W.24	27.3 S
	1873.	N.E. 5	N.E. 10	N. 8	N.W. 5	*N.W. 7	N
10	Jan.	2.2 S.W. 38	2.3 S. 36	3.1 S.W. 48	3.2 W. 36	3.3 W. 42	4.1 S
		N.E. 3	N.E. 5	S. 5	S.W. 6	*W. 4	W
11		4.3 W. 50	5.1 W. 36	5.2 S. 64	5.3 S. 60	6.1 W. 32	6.2 W
		W. 5	N.E. 2	N.E. 13	*N.E. 4	W. 12	W
12		20.3 S.W. 54	21.1 W. 16	21.2 S.W. 28	21.3 S.W. 34	22.1 S.W. 26	22.2 N
		S. 5	S. 1	S. 6	N.E. 4	*N.W. 4	N
13		26.2 W. 10	26.3 N.W.28	27.1 N. 10	27.2 S.W. 6	27.3 S.W. 16	28.1 W
		W. 3	E. 2	E. 1	N.E. 7	*N. 7	S
14	Feb.	3.1 W. 44	3.2 S.W. 40	3.3 W. 32	4.1 S.W. 46	4.2 W. 44	4.3 W
		S.W. 11	S.W. 6	S. 6	S. 7	*S.W. 6	N
15		6.3 W. 44	7.1 W. 14	7.2 S. 30	7.3 S. 34	8.1 S.W. 18	8.2 S
		S.W. 4	N. 2	N.E. 5	N.E. 10	*W. 8	W
16		21.1 W. 40	21.2 S. 38	21.3 S. 12	22.1 S.E. 26	22.2 S.E. 36	22.3 W
		N.E. 3	E. 12	*N.E. 12	W. 12	N.W.12	N
17	March.	2.3 W. 12	3.1 W. 37	3.2 N.E. 30	3.3 N.E. 42	4.1 S.E. 48	4.2 N
		N.W. 3	N. 8	*N.E. 13	N. 15	N. 9	N
18		7.2 W. 36	7.3 W. 50	8.1 W. 16	8.2 S. 46	8.3 N.W.126	9.1 N
		S. 6	S. 8	S. 9	S. 8	*W. 8	W
19		15.1 W. 12	15.2 S.W. 17	15.3 S. 38	16.1 S. 38	16.2 S.W. 52	16.3 W
		S. 5	S. 8	S.E. 8	*S. 8	W. 13	N
20		20.1 N.W. 5	20.2 S.E. 2	20.3 S.E. 84	21.1 S.E. 50	21.2 W. 12	21.3 W
		E. 6	E. 7	N.E. 14	*W. 10	W. 10	W
21		22.2 W. 32	22.3 W. 41	23.1 N.W.38	23.2 W. —	23.3 N.W.43	24.1 W
		W. 5	W. 7	S.W. 4	S. 8	*W. 9	N
22		25.2 S.W. 24	25.3 S.W. 40	26.1 S.W. 23	26.2 S. 54	26.3 W. 35	27.1 N
		N.E. 4	N.E. 5	N.E. 10	N.E. 9	*N. 8	N
23		28.3 W. 76	29.1 S.W. 34	29.2 S.W. 17	29.3 S.W. 50	30.1 W. 18	30.2 W
		S. 8	S. 5	S.E. 12	S. 13	*N. 7	W
24		30.3 N.W.24	31.1 N.W.42	31.2 S. 24	31.3 S. 82	32.1 S. 20	32.2 N
		S.W. 2	S. 4	*N. 9	W. 9	W. 4	W
25	April.	11.3 N.W.10	12.1 S. 36	12.2 N.E. 70	12.3 E. 96	13.1 N.E. 58	13.2 N
		N.E. 3	N.E. 7	N.E. 10	N.E. 11	N.E. 11	N
26		18.1 N. 60	18.2 S.E. 20	18.3 S.E. 6	19.1 calm.	19.2 W. 36	19.3 W
		N.E .10	N.E. 8	N.E. 4	N. 5	*N. 5	N
27		24.3 N. 5	25.1 W. 12	25.2 S.E. 5	25.3 S.E. 5	26.1 S.E. 10	26.2 W
		W. 7	W. 6	W. 6	W. 4	*N.W. 7	N
28	May.	12.1 N. 22	12.2 N.W.40	12.3 N.W.56	13.1 W. 44	13.2 N.W.51	13.3 N
		N.W. 4	N.W. 5	S. 5	S. 7	*W. 8	W
29		23.1 W. 24	23.2 W. 13	23.3 W. 60	24.1 W. 40	24.2 W. 60	24.3 W
		S. 4	S. 9	S. 9	S. 7	*W. 7	N

Winds on Mt. Washington compared with the surface winds.

1873. me.	3.1 N.W. 6 N.E. 8	3.2 W. 14 E. 6	3.3 W. 10 S. 7	4.1 N.W.24 S. 7	4.2 W. 36 S. 8	4.3 N.W.30 *N. 5
	18.3 N.W.48 S.W. 7	19.1 N.W.24 S.W. 4	19.2 W. 30 S.W. 5	19.3 W. 41 S. 7	20.1 N.W.26 *W. 6	20 2 N.W.36 N.W.12
ept.	0.1 W. 40 S.W. 5	0.2 N.W.30 W. 2	0.3 N.W.10 N.E. 3	1.1 S.W. 20 S. 7	1.2 S.W. 50 *W. 10	1.3 N.W.60 W. 12
ct.	6.1 N.W.35 S.E. 3	6.2 S.W. 8 N.E. 7	6.3 S.W. 18 N. 10	7.1 N.E 12 *N. 11	7.2 N.E. 20 N. 7	7.3 N. 30 N. 6
	10.3 S. 20 S. 2	11.1 S. 20 S. 4	11.2 S.E. 18 S. 6	11.3 S.E. 20 S. 4	12.1 S.W. 10 W. 3	12.2 W. 20 *W. 8
	26.1 N.W.20 S.W. 3	26.2 N.W. 8 S. 7	26.3 N.W.45 S. 12	27.1 S.W. 55 S. 16	27.2 N.W.35 *W. 12	27.3 N.W.45 N.W. 6
'ov.	6.3 N.W.38 E. 5	7.1 N.W 38 S. 4	7.2 S.W. 12 S.E. 9	7.3 calm. S.E. 6	8.1 S.E. 30 N.E. 9	8.2 N.W.28 *W. 6
	11.2 N.W.34 S. 4	11.3 N.W.10 S. 3	12.1 S.E. 46 S.E. 12	12 2 W. 22 W. 6	12·3 N.W.28 *W. 5	13.1 W. 30 N.W.12
	15.3 N.W. 6 E. 3	16.1 N.W.30 N.E. 4	16.2 S.E. 34 N.E. 7	16.3 S.E. 10 N.E. 7	17.1 S.E. 6 N.E. 7	17.2 S.E. 22 N.E. 10
			17.3 S.E. 56 N.E. 14	18.1 E. 48 N.W.17	18.2 S.E. 5 *N.W.12	18.3 N W.49 N.W. 7
ec.	2.3 S.W. 40 S. 10	3.1 S.W. 42 S. 6	3.2 W. 52 S. 12	3.3 S.W. 47 S. 11	4.1 S.W. 65 S. 16	4.2 W. 80 *W. 12
	12 2 N.W.28 W. 8	12.3 N.W.23 N. 4	13.1 calm. N.E. 7	13.2 S.E. 23 N.E. 11	13.3 calm. *N. 11	14.1 N.W.65 N.W. 8
	25.2 N W.28 N. 5	25.3 N.W. 3 N.E. 3	26.1 N.W.22 N.E. 6	26.2 E. 24 N.E. 8	26.3 calm. *N. 9	27.1 N.W.28 N. 7
	27.1 N.W.28 N. 7	27.2 N. 10 N.E. 6	27.3 S.E. 24 N.E. 11	28.1 N.E. 38 *N.W.17	28.2 N.W.96 N.W.12	28.3 N.W.86 N W. 6
1874. an.	7.2 S.W. 54 N. 4	7.3 S.W. 46 N.E. 1	8.1 S.E. 62 S. 13	8.2 S.W. 46 *S. 15	8.3 S.W. 45 S.W. 10	9.1 N.W.35 S.W. 6
	9.1 N.W.35 S.W. 6	9.2 N.W.16 S. 5	9.3 N.W.25 S. 2	10.1 S.W. 45 S. 7	10.2 W. 30 *S.W. 5	10.3 W. 15 S.W. 3
	13.2 N.W.10 N. 2	13.3 S. 15 E. 4	14.1 S.E. 34 N. 16	14.2 N W.10 N. 13	14.3 N.W.48 N.W. 7	15.1 N.W.42 N.W. 5
	21.3 N.W.64 S. 4	22.1 S.W. 58 S. 8	22.2 W. 60 S. 6	22 3 S.W. 52 S. 12	23.1 W. 37 S. 12	23.2 W. 80 *S.W. 13
	26.3 N.W.68 N. 1	27.1 N.W.35 S. 8	27.2 N.W.32 S. 7	27.3 W. 10 S. 8	28.1 N.W.26 S. 3	28.2 S.W. 50 *N.W. 9
eb.	9.2 N.W. 8 calm.	9.3 S.W. 4 calm.	10.1 N.W. 2 N.W. 5	10.2 N.W.45 N W 11	10.3 N.W 82 *N.W.12	11.1 N.W.90 N.W. 7
	12.2 N.W.36 E. 5	12.3 S.W. 20 S. 8	13 1 S.W. 44 S. 11	13.2 S.W. 48 S. 14	13.3 S.W. 68 S. 14	14 1 W. 72 *W. 12
	15.1 N.W.19 N. 5	15.2 S. 32 S. 10	15 3 S. 40 S. 12	16.1 S.W. 18 S. 12	16.2 N.W.55 S.W. 12	16.3 N.W.72 *W. 16
larch.	2.3 N.W.56 S. 11	3.1 N.W 38 S. 8	3.2 S.W. 60 S. 11	3.3 S.W. 96 S. 9	4.1 S.W. 74 S. 13	4.2 N.W.52 *N.W.14
	8.1 N.W.54 S. 6	8.2 N.W.50 W. 10	8.3 N.W.58 W. 11	9.1 N.W.50 W. 15	9.2 N.W 20 *N.W.15	9.3 N. 23 N.W.13
	18.1 W. 60 S. 9	18.2 W. 36 S. 6	18.3 W. 14 S. 2	19.1 W. 10 S. 2	19.2 W. 44 S. 12	19.3 W. 77 *W. 11
	21.2 N.W.38 S.W. 14	21 3 N.W 37 S.W 9	22.1 N.W.40 W 8	22.2 N.W.47 N.W.13	22 3 N.W.20 *S. 7	23.1 N.W.74 N.W.18
	25.2 N.W.54 S.W. 23	25.3 N W.78 S.W. 19	26.1 N.W.48 S. 8	26.2 N.W 34 N. 8	26.3 N W.59 *W. 13	27.1 N.W.67 N.W 11
pril.	1.2 N W.13 S. 8	1.3 W. 19 S.E. 5	2.1 N W 15 S. 4	2.2 S.W. 6 S. 12	2 3 W 24 S. 10	3.1 W. 24 *W. 8
	14.1 N.W.55 S. 9	14.2 W. 36 S. 13	14.3 W 47 S. 13	15.1 N.W.55 S. 8	15.2 S.W. 52 *S. 8	15.3 N W.40 W. 13
	19.3 N.W.72 N 7	20.1 E. 6 N.E. 11	20.2 S. 60 E. 9	20.3 S. 36 N.E 14	21.1 N.W 67 *S.W. 5	21.2 N.W 58 N.W.14
	24.3 N.W.23 calm.	25.1 calm. E. 6	25.2 E. 16 E. 9	25.3 E. 58 E. 13	26.1 E. 90 *N.E. 18	26.2 N. 50 N. 21
	28.1 N.W.86 N.W.11	28 2 S.E. 2 N. 5	28 3 S. 5 calm.	29.1 E. 35 N. 11	29.2 E. 18 N. 17	29.3 N.W.12 N. 18

Winds on Mt. Washington compared with the surface wind

61	1874. May.	4.3 N.W. 38 W. 7	4.3 N.W. 48 N.W. 6	5.1 N. 19 N.E. 7	5.2 N.W. 24 *N.E. 8	5.3 N.W. 36 N.W. 5	6.1
62		24.2 N.W. 18 S. 6	24.3 W. 10 S. 3	25.1 S.W. 56 S.E. 13	25.2 S. 88 S.E. 13	25.3 W. 56 *S.W. 11	[illegible]
63		30.1 N.W. 32 E 6	30 2 N.W. 30 S.E. 7	30.3 W. 36 S. 5	31.1 N.W. 38 S. 9	31.2 N.W. 60 *S.W. 20	31.3
64	June.	6.2 N.W. 20 E. 6	6.3 N.W. 24 S.E. 3	7.1 N.W. 20 S.E. 5	7.2 W. 36 S.E. 8	7.3 W. 68 S. 7	8.1 *
65		16.1 W. 20 S. 3	16.2 S. 36 S. 12	16.3 S. 60 S. 14	17.1 N.W. 36 S. 11	17.2 S. 20 S.W. 7	17.3 *
66		22.1 N. 28 S. 8	22.2 N. 44 S. 8	22.3 N.W. 42 S.W. 8	23.1 N.W. 60 S. 10	23.2 N.W. 34 *S.W. 9	23.3
67		27.2 W. 18 S. 9	27.3 W. 23 S. 11	28.1 N.W. 25 S. 7	28.2 N. 36 *S. 10	28.3 W. 54 S.W. 11	29.1
68	Aug.	0.1 N.W. 16 S. 5	0.2 S.W. 50 S. 14	0.3 N.W. 52 S.W. 11	1.1 N.W. 60 S.W. 10	1.2 N.W. 75 *W. 9	1.3
69	Sept.	29.1 W. 16 W. 5	29.2 S.E. 10 N.E. 11	29.3 E. 54 N E. 8	30.1 N.W. 30 *N.W. 14	30.2 N.W. 84 N.W. 13	30.3
70	Oct.	1.1 N.W. 20 W. 11	1.2 N.W. 36 W 13	1.3. N.W. 40 S. 8	2.1 S.W. 38 S. 13	2.2 N.W. 25 *S.W. 10	2.3
71		9.2 N.W. 56 S.W. 8	9.3 N.W. 55 S. 5	10.1 S.W. 30 S. 10	10.2 S. 35 S. 11	10.3 W. 40 *S.W. 12	11.1
72		16.3 N. 40 S.W. 6	17.1 W. 30 S.W. 6	17.2 W. 28 S.W. 10	17.3 N.W. 18 S.W. 7	18.1 N. 24 *N W. 6	18.2
73	Nov.	9.3 N. 56 S.W. 7	10 1 N. 74 W. 9	10.2 N. 70 W. 4	10.3 W. 46 S. 6	11.1 N. 78 *W. 5	11.2
74		19.2 N. 50 W. 6	19.3 N. 34 S. 4	20.1 S. 24 S. 5	20.2 S. 60 S. 7	20.3 S. 40 *S. 6	21.1
75		22.2 N. 8 N. 3	22.3 N.W. 18 S.E. 5	23.1 S.E. 54 S.E. 12	23.2 S.E. 35 S.W. 11	23.3 N.W. 32 *W. 8	24.1
76		28.1 N.W. 50 S.W. 5	28.2 S.W. 36 N.E. 3	28.3 S. 70 S. 7	29.1 S.W. 60 N.W. 13	29.2 N. 84 *W. 6	[illegible]
77	Dec.	16.1 N. 26 calm.	16.2 N.W. 38 S.E. 4	16.3 N.W. 8 S.E. 4	17.1 N.W. 54 S.E. 7	17.2 N.W. 35 W. 7	17.3 *
78		22.2 W. 40 S. 10	22.3 W. 40 S. 7	23.1 N. 40 S. 5	23.2 N.W. 48 S.W. 5	23.3 N.W. 24 S. 8	24.1
79	1875. Jan.	1.1 N.W. 80 W. 9	1.2 N.W. 45 S. 5	1.3 N.W. 48 S. 6	2.1 N.W. 14 S. 6	2.2 S.W. 30 *W. 10	2.3
80	1877. Jan.	1.1 N.W. 60 W. 7	1.2 N.W. 28 N.W. 2	1.3 calm. N.E. 8	2.1 N. 17 *N. 16	2.2 N. 56 N.W. 19	2.3
81		6.1 N.W. 48 S. 3	6.2 N.W. 42 S. 8	6.3 N.W. 40 N.E. 3	7.1 N.E. 50 N.E. 12	7.2 N.W. 96 *W. 15	7.3
82		7.3 N.W. 60 W. 9	8.1 N.W. 60 S. 8	8.2 N.W. 48 S. 15	8.3 N.W. 54 *W. 19	9.1 N W. 96 N.W. 9	9.2
83		19.1 N.W. 46 calm.	19.2 N.W. 46 S. 3	19.3 N.W. 62 S. 6	20.1 W. 48 S. 16	20.2 N.W. 86 *W. 24	20.3
84	Feb.	15.3 N.W. 50 S. 9	16.1 N.W. 24 S.W. 6	16.2 W. 36 S.W. 8	16.3 W. 24 W. 7	17.1 N. 24 W. 14	17.2
		17.3 N.W. 72 W. 13	18.1 N.W. 108 *W. 21			25.1 N.E. 24 *N. 11	25.2
85		23.1 N.W. 6 N.E. 5	23.2 N.E. 12 N.E. 4	23.3 N.E. 30 N E. 7	24.1 N.E. 54 N.E. 16	24.2 N.E. 36 N.E. 17	24.3
86	March.	1.2 N.W. 60 W. 7	1.3 N.W. 6 S. 5	2.1 S.W. 38 S.E. 11	2.2 S. 60 S. 13	2.3 S.W. 48 *S. 16	3.1
87		7 3 N.W. 66 N. 3	8.1 W. 42 S. 7	8.2 W. 54 S. 7	6.3 W. 72 S. 13	9.1 W. 66 S.E. 27	[illegible] *
88		12.2 N.W. 72 S. 6	12.3 calm. calm.	13.1 N.E. 6 N.E. 12	13.2 N.E. 6 N.E. 8	13.3 N.E. 4 calm.	14.1
		14.2 S. 60 S.E. 12	14.3 W. 40 S. 10	15.1 N.W. 18 N.W. 10	15.2 N.W. 72 *W. 18		
89		25.2 W. 24 N.E. 13	25.3 S.W. 24 E. 10	26.1 S.E. 72 N.E. 10	26.2 E. 48 N.E. 11	26.3 S.E. 78 N.E. 10	27.1
		27.2 S.E. 60 N. 9	27.3 S.E. 68 N. 3	28.1 S.E. 54 N. 11	28.2 S.E. 24 *N. 14	28.3 N.E. 18 N.W. 9	29.1

March, 1877. The total number of these cases is 89, and they are shown in Table I, in which two lines are given for each date; the first horizontal line shows the direction and force of the wind on Mt. Washington for six observations near the time of barometric minimum, and the second line shows for the same dates the average direction and force of the wind at five or six of the nearest surface stations. These data are designed to indicate the average direction of the surface winds near the base of Mt. Washington as accurately as it can be derived from the observations. For each case, the date of minimum pressure at the neighboring surface stations is indicated by an asterisk.

It will be noticed that for several observations preceding the minimum pressure, the surface winds generally blew from one of the points S., S.E., E. or N.E.; and that about the time of minimum pressure the wind changed to one of the points N., N.W., W. or S.W. For convenience I call the semicircle including the four former directions the *east quarter*, and the semicircle including the four latter directions the *west quarter*. On the summit of Mt. Washington we sometimes notice a similar change of wind near the time of minimum pressure, but not invariably. There are two cases in which the change of wind from one of the above mentioned quarters to the other did not occur in a decided manner either at the base or summit of Mt. Washington. These cases are Nos. 48 and 72. In each of these cases however there were a few of the surface stations at which the wind blew for a short time from the east quarter. In No. 48 at 9.2 the wind at Boston was east, while at Burlington and Portland it was south, but the velocity at all of the stations was so small that I have preferred to record it as a calm. The center of this depression was on the southeast side of Mt. Washington. In No. 72 the winds preceding the minimum pressure at several stations blew from the south, but the prevalent direction appeared to be S.W. This low center passed on the north side of Mt. Washington. These two cases should properly be deducted from the total number of cases, leaving the number of cases considered in the subsequent comparisons 87.

There were 40 cases in which the change of wind from the west to the east quarter was felt at the base but not at the summit of Mt Washington, that is, 46 per cent of the whole number of cases; and there were two cases in which this change occurred at the summit but did not occur in a decided manner at the base. These cases are Nos. 27 and 60. In No. 27 at 25.1 the wind at Burlington was south, and at Portland was northeast, but the prevalent direction of the surface winds in the vicinity of Mt. Washington appeared to be west. It will also be observed that the wind at this time on Mt. Washington was very

feeble. In No. 60 the wind at Boston at 28.3 blew from east, and at 29.1 from northeast, but there was no prevalent surface wind from the east quarter. The center of this low area passed on the south side of Mt. Washington. We thus see that occasionally when a low center passes near Mt. Washington, there is no prevalent surface wind from the east quarter although it occurs on Mt. Washington; but out of 87 cases which have been examined only two cases of this kind have been found; while in nearly half of the whole number of cases the surface wind blew for a time from the east quarter, but on the summit of Mt. Washington it blew uninterruptedly from the west quarter. In other words, in about half of the cases in which the barometer in New England sinks to 29·6 inches, the usual change of wind to the east quarter is observed at the surface stations, but this change does not reach to the summit of Mt. Washington.

We have now 45 cases in which the change of wind from the west quarter to the east occurred both at the summit and base of Mt. Washington. In 37 of these cases the change occurred first at the base, and in 8 cases the change occurred simultaneously at the summit and the base; that is, at an interval of less than 8 hours; and taking the average of all the cases we find that the change of wind at the surface stations usually occurs eleven hours earlier than it does on Mt. Washington.

In 23 cases the change of the wind back from the east quarter to the west quarter occurred simultaneously on the summit of Mt. Washington and at the base; that is, with an interval less than 8 hours; in 16 cases the change occurred first at the base, and in 6 cases the change occurred first at the summit. These six cases were Nos. 4, 10, 43, 50, 86 and 88. In four of these cases the wind on Mt. Washington blew from the east quarter at but a single observation, while at the surface stations the east wind continued during a period of from three to five observations, indicating that the influence of the movement of the lower stratum of the air was sensible on Mt. Washington for a few hours only, and then subsided. No. 88 is the only one of these cases in which the wind on Mt. Washington blew from the east quarter during more than two observations. Taking the average of all the cases we find that the change of wind back from the east to the west quarter generally occurs at the base of Mt. Washington sooner than on the summit by five hours.

If we take the average of the pressures at the center of those low areas in which the change of wind to the east quarter did not occur on the summit of Mt. Washington, we obtain the value 29·47 inches. If we take the average of the pressures at the center of those low areas in which the change of wind to the east quarter did occur on Mt. Washington we obtain 29·27 inches, which seems to indicate that the greater the depression

of the barometer, the greater is the height to which the system of circulating winds extends. It is, however, remarkable that in several of those cases in which the change of wind to the east quarter did not occur on Mt. Washington the depression of the barometer was very great. During the period of 32 months under examination, there were 8 cases in which the barometer fell below 29 inches: viz. Nos. 23, 38, 42, 60, 75, 81, 83 and 87, and in three of these cases, viz: Nos. 23, 83 and 87, no considerable change of wind occurred on Mt. Washington. In No. 23 the wind on Mt. Washington blew uninterruptedly from the west or southwest although the center of the low area passed south of that station. In Nos. 83 and 87 the wind on Mt. Washington was strong from the west or northwest.

I have also made a comparison of those cases in which an area of low pressure has passed over New England, when the barometer at Portland, Me., did not fall to 29·6 inches, and in seven-eighths of these cases during the continuance of this low pressure the wind on Mt. Washington did not at any time blow from the east quarter. I think we are therefore justified in inferring the following generalizations.

1. In a majority of those cases in which an area of low barometer passes over New England attended by the usual system of circulating winds at the surface stations, this system of circulating winds does not extend to the height of 6,000 feet.

2. When the depression of the barometer is unusually great, this system of circulating winds extends to the greatest height.

3. When during the progress of an area of low pressure, a system of circulating winds reaches to the summit of Mt. Washington, the change of wind to the east quarter usually begins at the surface stations eleven hours sooner than it does on the summit of that mountain; and the change back from the east to the west quarter usually begins at the base of the mountain five hours sooner than on the summit.

Abnormal storm paths.

In the hope of obtaining some information respecting the causes which determine the movement of areas of low barometer from place to place, I selected from the published volumes of the Signal Service observations those cases in which storm paths deviated most from their average course, and the results are shown in the two following tables, one containing those cases in which the direction of storm paths was most northerly, and the other containing those cases in which their direction was most southerly. Table II contains various particulars respecting eight storms whose course was nearly from south to north. Column 1st shows the number of the storm; column 2d shows the number of the observation; column 3d the date

of the observation; and column 4th the station at which the observed height of the barometer was least. This station was not generally at the center of the low area, but is presumed to have been not far distant from the center; column 5th shows the height of the barometer at the station named in column 4th; column 6th shows how much the barometer at the given date was below its mean height for that month as deduced from the observations of six years; column 7th shows how much the thermometer on the north side of the low area was depressed below its mean height for the hour of observation; column 8th shows how much the thermometer on the south side of the low area rose above its mean height for the hour of observation; column 9th shows the average humidity of the winds on the north side of the low area; column 10th the average humidity on the south side of the low area; column 11th shows the direction and velocity of the highest wind reported at any station on the north or west side of the low area; column 12th the direction and velocity of the highest wind reported at any station on the south or east side of the low area; column 13th shows the total rain-fall at all the stations east of the Rocky Mountains during the preceding eight hours; column 14th shows the total rain-fall at all the stations included within the same low area; and column 15th shows the direction of the center of the rain area from the center of low pressure for a time preceding the date of observation by four hours. When the center of low pressure is near the boundary of the United States it is generally impossible to determine from the observations where is the center of the rain area; and in such cases a blank is left in column 14th. When the center of the rain area coincided sensibly with the center of low pressure the syllable *cent.* is inserted. Table III contains similar particulars respecting six storms whose course was nearly from north to south. The last case in each of the tables was taken from the International series of observations in which the observations are given for only one hour of each day, and the rain-fall is the amount reported for the preceding twenty-four hours.

On comparing these two tables we find important differences in several particulars. In each case of Table II, with the exception of the last, the barometer became more depressed as the storm moved northward, and at the last observation of each case the average depression of the barometer below the mean was 0·26 inch greater than at the first observation. In each case of Table III the depression of the barometer increased for 16 hours or more, and then decreased, with the exception perhaps of the last case where the storm is only followed to Dodge City. In the other cases, the average depression of the barometer at the last observation was somewhat less than at the first

Storm.	No. of Obs.	Date.	Lowest Barometer.		Below mean.	Temp.		Hum.		Highest Wind.		Rain Fall.		
						N. wind.	S. wind.	N. wind.	S. wind.	North'ly.	South'ly.	Total.	In Low.	Which side.
		1872. Dec.		in.	in.	— °	+ °					in.	in.	
	1	19.1	Indianola.	29·70	·40	25	13	77	98	N. 12	S. 14	3·01	2·94	N.E.
	2	19.2	Nashville.	·79	·40	21	16	81	87	N.W. 17	S. 24	5·77	5·77	N.E.
	3	19.3	Louisville.	·62	·53	15	11	84	88	N. 20	S.E. 20	6·70	6·70	N.E.
	4	20.1	Buffalo.	·43	·56	19	12	80	89	N.W. 16	S.E. 24	14·37	14·37	N.E.
	5	20.2	Montreal.	·50	·58	12	8	79	88	N.W. 24	S.E. 18	5·28	5·28	
		1873. Jan.												
	6	1.3	Indianola.	·43	·70	8	12	81	87	N.E. 8	S.E. 16	0·64	0·54	N.N.E.
	7	2.1	St. Louis.	·53	·64	4	15	89	88	N.E. 11	S.E. 15	6·29	6·15	N.N.E.
	8	2.2	Milwaukee.	·23	·85	1	16	87	90	N.W. 29	S.E. 24	9·12	9·12	Cent.
	9	2.3	Milwaukee.	·07	1·01	2	11	82	90	N.W. 20	S. 20	6·28	6·28	
	10	3.1	Marquette.	·09	·98	3	19	82	90	N.W. 35	S. 20	7·84	7·37	
		Apr.												
I.	11	7.2	Indianola.	·66	·35	17	5	68	71	N. 25	S. 19	3·20	3·20	N.N.E.
	12	7.3	Memphis.	·68	·32	10	21	82	75	N. 28	S.E. 16	3·45	3·45	N.N.E.
	13	8.1	Cairo.	·64	·35	21	14	75	80	N. 34	S.E. 20	8·70	8·69	N.E.
	14	8.2	Louisville.	·52	·45	18	19	89	80	N.E. 32	S. 35	8·54	8·54	N.E.
	15	8.3	Chicago.	·54	·42	7	18	83	82	N. 26	E. 33	4·48	4·48	Cent.
	16	9.1	Escanaba.	·42	·55	17	15	85	85	N. 16	S.E. 32	3·75	3·75	
	17	9.2	Marquette.	·42	·58	12	14	67	83	N.W. 23	S. 32	3·98	3·98	
		Oct.												
7.	18	19.2	Charleston.	·64	·45	4	3	66	91	N.W. 12	E. 13	6·84	6·84	N.
	19	19.3	Norfolk.	·52	·58	10	8	77	94	N. 16	S.E. 24	9·82	9·82	N.
	20	20.1	Cape May.	·45	·62	19	16	82	95	N. 28	S.E. 32	17·65	17·65	N.
	21	20.2	Phila'phia.	·26	·82	14	11	56	93	N. 36	E. 42	12·27	12·27	N.
	22	20.3	Pittsburgh.	·38	·63	15	13	78	95	N. 28	S.E. 32	9·86	9·86	N.
	23	21.1	Erie.	·28	·69	13	11	78	83	N. 32	S. 24	5·90	5·90	N.W.
	24	21.2	Alpena.	·36	·58	14	9	65	78	N. 20	S. 28	3·01	3·01	N.W.
		1874. Jan.												
	25	5.3	Jacks'ville.	·95	·25	8	12	81	91	N.E. 20	E. 24	3·05	3·04	
	26	6.1	Montgom'y.	·90	·32	8	17	86	95	N.E. 18	E. 24	8·82	8·78	N.N.E.
	27	6.2	Augusta.	·74	·46	4	11	79	89	N. 16	S. 16	12·48	12·48	N.
	28	6.3	Augusta.	·61	·59	0	16	83	89	N. 24	S.E. 24	8·35	8·35	N.
	29	7.1	Lynchburg.	·57	·61	1	26	82	95	N.E 18	S.E. 24	11·81	11·81	N.N.E.
	30	7.2	Pittsburg.	·46	·67	7	22	88	93	N.W. 18	S.E. 18	9·48	9·48	N.E.
	31	7.3	Cleveland.	·54	·56	1	26	85	92	N. 12	S. 12	6·27	6·27	E.N.E.
	32	8.1	Oswego.	·46	·60	3	33	81	97	N.W. 12	S. 20	5·65	5·65	E.N.E.
	33	8.2	Ottawa.	·31	·67	2	29	72	87	N.W. 18	S. 20	1·68	1·68	
		Mar.												
.	34	6.1	Ft. Gibson.	·40	·56	17	10	86	85	N. 12	S.E. 24	10·93	10·93	N.E.
	35	6.2	Keokuk.	·23	·78	9	16	74	83	N. 30	S. 29	5·16	5·06	E.N.E.
	36	6.3	Dubuque.	·16	·86	5	21	77	87	N.W. 35	S.E. 27	5·76	5·22	N.E.
	37	7.1	Milwaukee.	·17	·86	13	3	7	89	N.W. 32	S. 25	8·82	8·77	
	38	7.2	Alpena.	·24	·76	11	9	75	84	N.W. 28	E. 20	3·92	2·32	
		1877. Feb.												
I.	39	28.2	Indianola.	·90	·23	15	8	52	82	N. 12	E. 13	1·12	1·11	N.
	40	28.3	Galveston.	·88	·22	6	7	49	93	N.E. 12	E. 12	2·31	2·31	N.
		Mar.												
	41	1.1	Shreveport.	·73	·33	6	4	68	95	N.W. 12	S.E. 14	4·15	4·01	Cent.
	42	1.2	Memphis.	·56	·52	8	2	69	93	N.E. 10	S. 20	9·43	9·43	N.E.
	43	1.3	Cairo.	·42	·65	4	9	85	88	N.E. 16	S. 28	5·17	5·17	E.
	44	2.1	Chicago.	·17	·85	4	16	84	87	N.W. 16	S.E. 24	13·62	11·45	N.E.
	45	2.2	Saugeen.	·12	·87	3	12	78	90	N.W. 24	S. 40	18·52	18·52	
		Dec.												
II.	46	21.1	Concho.	·56	·44	7	14	82	89	N. 12	S.E. 24	12·00	12·00	N.E.
	47	22.1	Dodge City.	·37	·43	7	35	88	93	N.W. 32	S.E. 24	11·34	11·34	E.N.E.
	48	23.1	Bismark.	·55	·40	8	37	82	93	W. 12	S.E. 20	12·43	12·43	E.N.E.
m.						9.5	14·7	78	88	20.8	23·0		6·89	

Table III.—*Storms Moving Southward.*

No. of Storm.	No. of Obs.	Date.	Lowest Barometer.		Below mean.	Temp. N. wind.	Temp. S. wind.	Hum. N. wind.	Hum. S. wind.	Highest Wind. North'ly.	Highest Wind. South'ly.	Rain Fall. Total.	Rain Fall. In Low.	Rain Fall. Which side.
		1877. Jan.		in.	in.	— °	+ °					in.	in.	
I.	1	3.3	Pembina.	29·91	·20		2		70	N.W. 16	S. 14	0·82	0·00	
	2	4.1	Ft. Sully.	·83	·27	3	5	82	79	N.W. 28	S. 16	0·99	0·22	
	3	4.2	Ft. Sully.	·67	·43	0	5	74	77	N.W. 28	S. 13	1·11	0·63	E.
	4	4.3	Omaha.	·80	·33	3	9	86	72	N. 25	S. 10	0·54	0·48	E.
	5	5.1	Ft. Gibson.	·80	·36	2	3	86	78	N.W. 34	S. 7	0·49	0·30	S.S.E.
	6	5.2	N. Orleans.	·90	·28	6	0	76	68	N.W. 20		0·96	0·90	S.E.
II.	7	9.3	Virginia C.	·46	·19		7		80		S. 18	0·70	0·59	E.
	8	10.1	Virginia C.	·31	·34	14	12	75	81		S.E. 24	0·80	0·72	E.S.E.
	9	10.2	N. Platte.	·07	·78	20	17	73	81	N.E. 24	S.E. 18	0·97	0·77	E.
	10	10.3	N. Platte.	·03	·82	22	10	76	76	N.E. 24	S.E. 12	1·24	0·41	Cent.
	11	11.1	Ft. Gibson.	·64	·52	35	22	83	81	N.W. 25	S.E. 12	2·03	1·74	E.N.E.
	12	11.2	Denison.	·76	·45	29	19	77	74	N.E. 32	S. 20	6·88	0·20	N.
	13	11.3	Corsicana.	·95	·25	35	20	71	84	N.E. 34	S. 12	2·98	0·76	N.
	14	12.1	Indianola.	30·05	·09	21	24	82	91	N. 20	S. 10	1·16	0·99	N.N.E.
		Feb.												
III.	15	17.3	Ft. Garry.	29·79	·39		20		77		S. 12	0·34	0·00	
	16	18.1	B'kenridge.	·73	·41		18	78	78	N.W. 30	S. 16	0·42	0·00	
	17	18.2	Milwaukee.	·55	·52	3	16	63	64	N.W. 26	S.E. 20	1·55	0·99	E.S.E.
	18	18.3	Toledo.	·58	·50	6	14	75	66	N. 26	S. 15	1·02	0·98	E.N.E.
	19	19.1	Pittsburgh.	·59	·50	11	5	76	62	N.E. 24	S. 4	0·42	0·27	N.E.
	20	19.2	Norfolk.	·63	·47	11		64		N.W. 20	S.W. 14	0·46	0·39	N.E.
	21	19.3	Wilm'gton.	·76	·37	7		63		N. 32		0·53	0·43	
	22	20.1	Savannah.	·88	·28	6		72		N.E. 30		1·42	0·39	
IV.	23	20.3	Pembina.	·64	·49		26		77		S. 10	0·03	0·00	
	24	21.1	B'kenridge.	·54	·60		27		75		S. 12	0·00	0·00	
	25	21.2	Duluth.	·35	·72		43	63		N.W. 45	S. 25	0·15	0·15	
	26	21.3	St. Paul.	·38	·70		23	76		N.W. 27	S. 21	0·19	0·19	
	27	22.1	LaCrosse.	·46	·65		28	79	63	N.W. 30	S. 21	0·18	0·18	
	28	22.2	Davenport.	·53	·60	0	21	61	56	N. 30	S. 13	0·79	0·78	S.
	29	22.3	St. Louis.	·58	·53	4	20	71	57	N. 24	S. 8	1·80	1·80	S.S.E.
		Mar.												
V.	30	21.3	N. Platte.	·19	·45	15	24	78	58	W. 28	S. 14	9·44	0·00	
	31	22.1	Omaha.	·46	·55	19	21	76	63	N.W. 20	S.E. 14	8·59	0·13	
	32	22.2	Dodge City.	·07	·56	13	21	58	59	N. 44	S. 26	5·21	0·27	N.E.
	33	22.3	Ft. Gibson.	·66	·30	19	19	80	57	N.E. 40	S.E. 16	1·30	0·19	N.W.
	34	23.1	Ft. Gibson.	·73	·23	19	17	79	73	N. 24	S.E. 8	3·81	1·11	N.
	35	23.2	Corsicana.	·67	·33	14	15	62	45	N.E. 30	S.E. 17	4·81	1·31	N.
	36	23.3	Indianola.	·83	·25	10	15	73	69	N. 22	S. 11	3·70	2·93	N.
		1878. Feb.												
VI.	37	18.1	Virginia C.	·44	·20	6	18		75		S. 16	4·82	0·20	
	38	19.1	B'kenridge.	·38	·76	8	21	71	72	N. 12	S.E. 17	1·56	0·04	
	39	20.1	Dodge City.	·06	·74	0	28	86	76	N.W. 19	S. 18	3·46	2·89	E.
Means.						12.0	17·1	74	71	27·1	14·8		0·57	

observation, and less than half of what it was at an intermediate date. In table II the average temperature of the winds on the north side of the low area was 9·5 degrees below the mean for that time and place; and the average temperature of the winds on the south side of the low area was 14·7 degrees above the mean for that time and place. In table III the average temperature of the winds on the north side of the low area was 12 degrees below the mean, and on the south side was 17 degrees above the mean. The blanks in columns seven and eight of table III result from the center of least pressure being near the boundary of the United States, so that the signal service stations do not furnish the required data. In both tables the average humidity of the north winds was nearly the same, but the humidity of the south winds was very much the greatest in table II. In table II the average velocity of the south winds was ten per cent greater than that of the north winds. In table III the average velocity of the north winds was about double that of the south winds. In table II the average rain-fall in eight hours within the low areas was 6·89 inches; in table III the average rain-fall was 0·57 inch, and in a majority of the cases in this table the average rain-fall in eight hours was only 0·14 inch.

The most remarkable circumstance which characterizes these two classes of storms is the difference in the amount of rain-fall. In the cases shown in table II the rain-fall was enormously great, and this appears to be the general characteristic of those storms which originate near the Gulf of Mexico. In my seventh paper, I gave a list of all the cases contained in the volumes of the Signal Service observations which had then been published, showing a total rain-fall of eight inches in eight hours at all of the stations. More than two-thirds of all these storms originated on or near the Gulf of Mexico, and a majority of the remaining cases occurred in summer. One reason why these storms are attended by a great fall of rain appears to be that the south wind is charged with a large amount of vapor from a warm sea. From table II it appears that this south wind is warm, moist, and pushes northward with great force.

The principal object which I had in view in preparing these tables was to discover, if possible, the reason why these storms pursued so unusual a path. The average course of the eight storms in table II was only 20 degrees east of north. One of them moved almost exactly north, and another deviated sensibly to the west of north. Can any reason be assigned for this unusual course? I have endeavored to determine whether there was any connection between the course of the storm and the rain-fall which accompanied it. Plate I of my 7th Paper shows the curves of equal rain-fall for the eight hours preceding

$7^h\ 35^m$, Oct. 20, 1873, and corresponds to No. 20, table II of the present Article. At that date the center of low pressure was moving almost directly towards the center of the rain-area. Plate I accompanying the present Paper, shows the isobars for Oct. 21.1, 1873, and the dotted line shows the area over which the rain-fall for the preceding eight hours amounted to at least one-fifth of an inch. The rain-fall at Cleveland was ·75 inch; Alpena ·58 inch; Rochester ·49 inch, and Saugeen ·49 inch. It will be perceived that during these eight hours the storm center had been moving almost exactly towards the center of gravity of this rain-area. There was also a rain-area extending along the New England coast from Boston to Eastport which did not appear to exert any appreciable influence upon the progress of the storm. I have made a similar comparison for each date in table II and find that in each case the storm center was moving nearly towards the center of the rain-area. In more than half of the cases the storm appeared to be moving exactly towards the center of the rain-area. In four of the cases the rain center appeared to be a little westward of the storm path, and in twelve cases it appeared to be a little eastward, but in only two or three cases did it deviate as much as 45° from the direction in which the storm center was moving. This coincidence seems to favor the conclusion that in a great storm the condensation of the aqueous vapor is an efficient cause which controls the movement of the winds.

Table III shows results very different from table II. In six of these cases no rain was reported at any station within the area of low pressure during the preceding eight hours; in 23 of the cases the total rain-fall during the preceding eight hours at all the stations within the low area was less than half an inch; and in only five of the cases did the total rain-fall in eight hours exceed one inch, and in each of these five cases there appears to have been a special reason for the greater rain-fall. In No. 11 the rain center was about 600 miles northeast of the center of low pressure, and the succeeding observation shows that there was another low center in Canada which mainly controlled the movement of the winds throughout this rain-area. In No. 29 the character of storm No. IV had already changed, and the subsequent course of the storm was nearly east. In Nos. 34, 35 and 36 the greater rain-fall is partly explained by the proximity of the low center to the Gulf of Mexico. In No. 39 the rain-fall is given for a period of 24 hours. Thus we see that an area of low pressure may be formed with very little rain, and apparently with none at all. Moreover in these cases the storm center did not generally follow the rain-area but moved away from it. Plate II accompanying this paper shows the isobars for Jan. 4, 1877, at $4^h\ 35^m$ P. M., indicating a low center near Ft. Sully.

The rain-fall reported for the preceding 8 hours was as follows: 1. Milwaukee, 0·14 inch; Marquette, 0·10; Grand Haven, 0·08; Escanaba, 0·05; Port Stanley, 0·02; Detroit, 0·01; and Toledo, 0·01, amounting together to 0·41 inch. Around the first four of these places I have drawn a dotted line, which is designed to represent the area over which the rain-fall was at least 0·05 inch. 2. A rain-fall of 0·09 inch was reported at Bismark and of 0·05 at Ft. Sully. I have also drawn around these places a dotted line representing the area of 0·05 inch rain-fall. 3. A rain-fall of 0·08 inch was reported at North Platte. Thus we see that the principal rain-fall was about 600 miles east of the low center, and the low center traveled southward apparently uninfluenced by this rain-fall. There was a smaller rain area which was nearly concentric with the area of low pressure, and there was a very slight fall of rain on the south side of the low center. I have made a similar comparison for each of the dates of observation, and find the following results: In seven of these cases the principal rain center was about 350 miles north of the center of the low pressure; in four of the cases it was on the northeast side, and at a distance of about 500 miles; in eight of the cases it was on the east side, distant about 600 miles; in one case it was on the northwest side; in one case it was on the southeast side; and in only three cases was the center of the rain-area nearly south of the center of low pressure, viz: Nos. 5, 28 and 29. In the last case the storm, instead of following the rain towards the south, immediately changed its course and moved off towards the east. Thus, out of thirty-nine cases we find only one case in which the storm seemed to follow the rain-area, but in half of the cases the storm traveled almost directly away from the rain-area, and in nearly all of the remaining cases the course of the storm was nearly at right angles to the direction of the rain-area. These facts seem to show that in these cases the rain-fall exerted no appreciable influence upon the course of the storm, and therefore no appreciable influence upon the fall of the barometer. This conclusion is confirmed by the observation of the clouds. In all the cases given in table III, the average cloudiness on the south side of the low area was less than one-half; and in several cases the sky was *entirely cloudless* at every station on the south side of the low area. This was true for Nos. 15, 16, 17, 23, 24, 30, 31 and 32.

This evidence appears to me to show that heavy and extensive precipitation does not invariably precede the first formation of depression areas and accompany their expansion, as has been claimed. These depression areas increased in intensity when the rain-fall was nearly zero, and while the sky on the south side was not generally overcast with clouds, but in several cases was almost entirely clear. In

the United States, depression areas do not generally begin with extensive precipitation, but the rain-fall is a concomitant after the system of circulating winds has become pretty well established. The depression of the barometer is the result of a system of circulating winds, and the most frequent cause producing such a system appears to be two or more areas of high pressure at a considerable distance, (frequently 1,400 miles) from each other. Differences of temperature and of humidity are also important agents in producing and sustaining such a system of winds. When a system of circulating winds has been formed over a large extent of country, there almost invariably results a fall of rain; and if the rain-fall is abundant, and extends over a large area, it becomes a very important agent in modifying the direction and force of the winds.

The principal question still remains undecided, why did the storms in table II pursue a course so nearly from south to north, and those in table III, a course nearly from north to south? The average course of storm paths appears to be determined mainly by the average system of circulation of the atmosphere near the earth's surface, and occasional departures of storm paths from this average track appear to be mainly due to causes which render the general movement of the atmosphere at such times different from the average movement. In table II it is seen that the average velocity of the winds on the south side of the storm's center was somewhat greater than on the north side. This seems to indicate that at these times a wind from the south or southeast pressed towards the storm-area with unusual force. This wind extended to a height greater than 6,000 feet, as is shown by the observations on Mt. Washington whenever a storm center came into the neighborhood of that station. The following observations show the direction and force of the wind on that mountain during the progress of storm No. IV. Oct. 20.1, wind S.E. 75 miles; Oct. 20.2, wind S.E. 78 miles; Oct. 20.3, wind S. E. 50 miles; Oct. 21.1, wind S. E. 55 miles; Oct. 21.2, wind S.E. 38 miles. The observations also show that this south current extended to the height of the upper clouds. This is seen from Plate I, where the arrows indicate (*not* the direction of the surface winds), but the direction of the upper clouds, according to the reports of the Signal Service observations for Oct. 21.1, 1873. These arrows conform in a remarkable degree to the direction of the surface winds, and seem to indicate that the system of circulating winds which prevailed at the surface of the earth, extended to a height greater than 6,000 feet into the region of the upper clouds; a height which is very uncertain and difficult to estimate. The only important exception to the rule here

stated is the observation at Davenport, which appears suspicious, since at the afternoon observation of the same day, the upper clouds were reported from the northwest. Generally throughout the eastern half of these low areas the lower clouds were dense and unbroken, so that there was no opportunity to obtain observations of the direction of the upper clouds, but in several cases observations were made which indicated a circulation of the winds at the height of the upper clouds similar to that described for Oct. 21.1. This is seen in the observations of Nos. 8, 24, 29, 30, 35 and 36.

In table III the velocity of the wind on the north side of the low areas was nearly double that on the south side, and this northerly wind extended to a considerable height, as is shown by the observations on Pike's Peak. The following observations show the direction and force of the wind on that mountain during the progress of storm No. I. Jan. 3.3, wind north 30 miles; Jan. 4.1, wind north 42 miles; Jan. 4.2, wind north 32 miles; Jan. 4.3, wind north 38 miles; Jan. 5.1, wind northeast 20 miles; Jan. 5.2, wind north 36 miles. This northerly current extended to the height of the upper clouds. This is seen from Plate II, where the arrows indicate the direction of the upper clouds according to the reports of the Signal Service observers for Jan. 4.2, 1877. These arrows indicate a movement of the upper clouds from the west or northwest over nearly the whole of the United States from the Pacific Ocean to the Atlantic; and throughout the western half of this region the movement was mainly from the northwest. At no station were the upper clouds reported as moving from the southeast, east or northeast, and at only one station were they reported from the south. At the thirty-nine dates enumerated in table III, there were only five cases in which the upper clouds were reported from the east at any station which could be regarded as included within the system of circulating winds here considered; there were five cases in which the clouds were reported from the southeast, and thirty-one cases in which the clouds were reported as moving from the south, and about half of these cases occurred Feb. 22d, when storm No. IV was losing its previous character and preparing to change its course from south to east. These facts seem to indicate that the surface winds which prevailed on the south and east sides of the low areas enumerated in table III, were not only dry and feeble, but extended to a less height than the southerly winds which attended the storms enumerated in table II.

These facts seem to indicate that at the time of the observations in table II, there was an unusually strong current from the south or southeast, which reached to a height of over 10,000 feet, and swept over a considerable portion of the United States;

while at the time of the observations in table III, there was an unusually strong current from the north or northwest, which also reached to a height of more than 10,000 feet, and swept over the United States from the Pacific Ocean to the Atlantic.

The cases enumerated in table III are remarkable on account of the long continuance of the movement of storm centers from north to south, but the published volumes of the Signal Service observations show many other cases in which storms pursued a similar course for twenty-four hours or more.

In preparing the materials for this article, I have been assisted by Mr. Henry A. Hazen, a graduate of Dartmouth College of the class of 1871.

Art. II.—*Silurian Formation in Central Virginia;* by J. L. Campbell, Washington and Lee University.

Limits.—What is known as the "Great Valley of Virginia" occupies a belt of country extending entirely across the State from the Tennessee line on the southwest to the Potomac on the northeast—including Jefferson and part of Berkeley County, now a portion of West Virginia. It has mountain boundaries throughout its whole extent. On its southeastern margin it is separated from what is called "Piedmont Virginia," by the Blue Ridge and its southwest prolongations, Poplar-Camp and Iron Mountains. On the northwest side we find a somewhat irregular line of broken ridges bearing different names at different points. Through several of the southwest valley counties it is called "Walker's Mountain." In Botetourt, Rockbridge and Augusta, it is called "North Mountain," while through the remainder of the distance to the Potomac it is called "Little North Mountain." The length of the Valley, from the Tennessee line to the Potomac, is about three hundred and thirty miles. Near its southwest extremity, in Washington County, it is about twelve or fifteen miles wide, and becoming gradually wider it extends towards the northeast. We find it in Rockbridge and Augusta varying in breadth from twenty to twenty-five miles. Its total area, embracing the contiguous mountain slopes on each side, is not much short of 6,000 square miles.

Its Topography.—With the exception of a limited belt occupied by the Massanutton range in its northeast parts, and some strips covered by outliers of North and Walker's Mountains, this extensive zone has for its surface one continuous outcropping of the Lower Silurian rocks. Before examining into the geological features of this interesting region, it will be well to take a bird's-eye view of its topography. (1.) It lies between two elevated mountain ranges—the Blue Ridge on the

ɔutheast rising to heights ranging generally between 2000 and 000 feet above tide-level; and the North Mountain range on ıe northwest, almost equally high at many points. (2.) The xial line of the Blue Ridge (which consists chiefly of Archæan ocks) has but few gaps through which streams of water can ass. Not a single outlet of any considerable size is found for he waters of the valley through this ridge anywhere between Iarper's Ferry on the Potomac and Balcony Falls on the ames—a distance of one hundred and fifty miles. The only ther water-gaps are the one through which the Roanoke afterwards the Staunton) River passes towards the southeast, nd the narrow, rugged ravines by which the waters of New River (Kanawha) and some of its tributaries run down from he Plateau formed by the bifurcation of the Blue Ridge owards its southwest extremity. But along the northwest ide of the axial ridge, throughout the greater part of its xtent, we find a large number of short broken ridges and rregular peaks, forming sometimes double, and often triple, ines nearly parallel with the main mountain, and indicating by heir position and structure that they were once continuous idges that have since been fractured and cut into deep gorges, hrough which small streams of water now run down into the imestone valley below. These broken ridges consist of Primordial rocks. The mountains on the northwest are far less egular and continuous than the main Blue Ridge, and are raversed by numerous water-gaps. Here the Upper Silurian Medina) Sandstones constitute the material of which most of he ridges are constructed, and the heavy beds are frequently ırched or folded, and cut through by ravines of considerable xtent and grandeur, like that through which New River makes ts way towards the Ohio, or the beautiful arch at Clifton Forge, or the grand "Goshen Pass" between the Chesapeake and Ohio Railroad and Lexington.

(3.) Those who have not visited this section of the State must not imagine that the "valley" is one vast continuous plain like some of the western prairies. It is a land of "hill and dale, of water-brooks and fountains of water." Its limestone and cherty ridges are frequently of such dimensions that in many parts of the world they would be called "mountains;" and where they are cut by the bold and rapid streams that abound here, they present many steep and naked cliffs, sometimes more than two hundred feet in height above the water. Such natural sections present features of great interest to the geologist; and afford important aid in ascertaining the real structure and relative position of the several sub-divisions of this, the most remote age of paleozoic history.

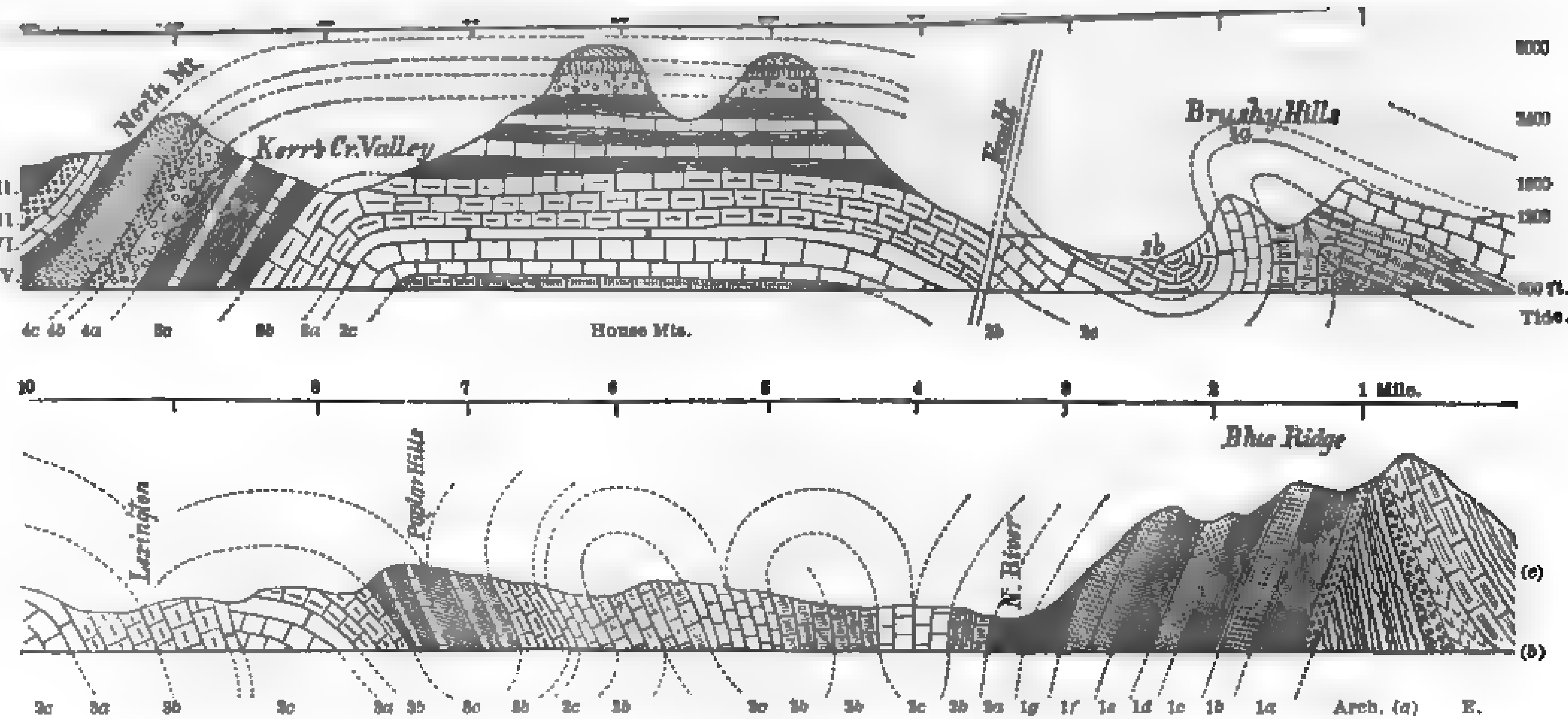
(4.) Any good map of Virginia will show that this valley is

not single, whether viewed lengthwise or crosswise. From a few miles southwest of Winchester to a point nearly opposite Harrisonburg, it is divided into two subordinate valleys, by the Massanutton Mountains—a long belt of ridges of Upper Silurian and Devonian rocks that withstood the denuding agencies that uncovered so many hundreds of square miles of the Lower Silurian limestones. Less extensive ridges also interrupt the continuity on the northwest side; and some of them, like the House Mountain,* across which the accompanying section passes, present striking examples of mountains *left* in isolated positions by the sweeping away of the once adjacent rocky masses through the powerful denuding agencies of water and ice. That such agencies have operated in this region on an extensive scale will be considered more fully hereafter.

The cross divisions of the valley are marked by the watersheds that determine its drainage. Southwest of Wythe County we find the waters carried off by the Holston into the Tennessee River. Wythe, Pulaski and part of Montgomery, are drained by New River, which runs down from the Blue Ridge plateau, crosses towards the northwest and makes its way to the Ohio. Thus we have "New River Valley." A small portion of Montgomery and nearly all of Roanoke County, are drained by the Roanoke River—one of the three rivers that have cut water-gaps through the Blue Ridge in a southeasterly direction. Next to this "Roanoke Valley" comes the upper "James River Valley," occupied by Botetourt and Rockbridge. Extending from the water-shed (crossing near the line between Rockbridge and Augusta) to the Potomac, we find the extensive "Shenandoah Valley."

(5.) *Elevations.*—At Harper's Ferry, where the Potomac leaves the Great Valley, the height above tide-level is only about two hundred and forty feet; but when we reach the head waters of the Shenandoah, we have arrived at a water-shed having an average height of nearly 1800 feet. Then, in passing on to the south corner of Rockbridge, we come to the "pass" of the James, at Balcony Falls, having an elevation of about 700 feet. The Roanoke Valley has about the same average elevation as that of the James Valley, 1200 feet; but on rising to the margin of New River Valley, near Christiansburg, in Montgomery County, we are about 2000 feet high; and on the southwest margin, at Mount Airy—the summit of the A. M. & O. Railroad—2600 feet. Many points on the Blue Ridge are not higher than this highest part of the great limestone valley. At the Tennessee line the height is less than 1700 feet.

* This is often spoken of as if it were a single mountain—and so it appears to be as seen from Lexington—while, in reality, there are two short parallel ridges nearly a mile apart, cut off abruptly at both ends.



SECTION OF SILURIAN FORMATION, ROCKBRIDGE CO., VA.—From S. E. to N. W. 20 Miles.

DESCRIPTION OF SECTION.—1. The leading divisions of strata are denoted by the numbers 1, 2, 3, 4; V, VI, VII, VIII, corresponding with the Pennsylvania series (Rogers) 2. Sub-divisions are indicated by letters attached to the numbers, as 1*a*, 1*b*, 2*a*, etc. 3. On the right-hand end below (the proper place to begin the examination), the Archaean rocks are marked, "Arch. (*a*), (*b*), (*c*);" while an eruptive mass protruding near the crest of the Blue Ridge is marked, E. 4 The beds of sandstone are *dotted*,—coarsely when more or less conglomerate; beds of shale have closely *ruled* lines; limestone strata are *blocked*, some having *longitudinal* and some *cross* rulings, to distinguish *epochs*. 5. The feldspathic rocks east of Blue Ridge have double longitudinal lines. 6. Heights above tide level are indicated on the right of the upper division of the section.

Here, then, we have a plateau, rather than a valley, with an average elevation above the sea of about 1200 or 1300 feet. This is much above the average elevation of the Mississippi Valley. It is in reality a part of the great belt of uplift that constitutes the Appalachian Range, but erosive agencies have stripped it of the greater part of its mountain-making masses. The Blue Ridge, which now forms its southeast border, was once the shore-line of the great primal ocean that covered the Mississippi Valley (including "Appalachia") during the remote ages of geological history.

At present the streams of water in the valley tend towards the southeast margin all the way from the Potomac to Salem, in Roanoke County. This is most strikingly the case in the basins drained by the Roanoke and the James Rivers, thus indicating less elevation on that side than on the other. I think we shall learn hereafter that this is most probably the result of difference in the amount of denudation on the two sides.

This brief summary of the most conspicuous physical features of the Great Valley and its surroundings is deemed sufficient to give the reader a tolerably distinct, though very general view of the *present* surface formed by the outcropping of the most extensive exposure of Lower Silurian rocks in Virginia. There are other less extensive exposures of the same rocks forming subordinate limestone valleys, but they must be left out of our present discussion.

Geology.—My purpose is to give in the first place a section extending from the Blue Ridge to the North Mountain, embracing some of the Archæan rocks at one extremity, and of the Devonian at the other. The discussion of this, with its divisions and sub-divisions, and some leading peculiarities of each, will, I think, illustrate the geology of this middle part of the State in a manner, and to an extent, not hitherto attempted by any one.

I am indebted to the partial survey of Virginia, made under the direction of the venerable and distinguished geologist, Professor W. B. Rogers, for guidance and aid in my own investigations and for many of the facts contained in this communication. The line of section here given has been carefully explored and re-explored throughout its whole extent, several times. It crosses a portion of the valley not heretofore represented in section, so far as I know; and while it may be regarded, to a certain extent, as typical of this region of the State for some miles on each side of its line, it presents some peculiarities worthy of special notice. These will be discussed in future. For the present a general description must suffice.

The southeast extremity is on the slope of the Blue Ridge beyond Robinson's Gap, and extends one mile past the line

between Rockbridge and Amherst Counties; while the northwest reaches about a mile beyond the crest of the North Mountain to the valley of the Rockbridge Alum Springs, where it cuts the Devonian shales from which the waters of those springs flow. A subordinate ridge of Medina sandstones, however, rises in the valley between the end of the section and the Springs.

The first general division includes the metamorphic and eruptive rocks of the main Blue Ridge. The other general divisions are those adopted by Professor Rogers in his survey of the State (1836–41). Only Nos. I to VII are included. The sub-divisions into which each of these is here divided are my own, and may be regarded as representative (with local modifications), not only of the limestones of the Great Valley, but also of the shales and sandstones of the bordering mountains and outlying ridges on both sides. They are marked, *a*, *b*, *c*, etc., in ascending order, and will be found to correspond with many of the subdivisions given by Professor Dana in his Manual of Geology (ed. 1875).

There is no natural section or gap through the metamorphic and eruptive rocks at this point on the Blue Ridge, but the outcrop is quite distinct, except that of a mass of syenite (E) protruded among the stratified rocks. The crest of the ridge is marked by a heavy bed of syenitic gneiss (or stratified syenite), (*b*) which might readily be taken for an igneous rock—so greatly has it been metamorphosed. This, with the thinner beds of like composition, and the interstratified slates (*c*) all dip steeply to the S.E.—or rather S.S.E. Beneath the mass of syenite we find first gneissoid rocks with considerable quantities of epidote; and under these, slates and sandstones, all dipping conformably with those above. These are *a* of the metamorphic group on the section.

Against the upturned edges of these metamorphic strata we find the lowest of the Primordial beds, resting *unconformably*, and dipping in the opposite direction. Here begins No. I of Professor Rogers's divisions. It might be subdivided into very many alternations of sandstones and shales, but I have preferred to limit the number to *seven*, that are quite constant in their general features for many miles along the N.W. face of the range. At the grand natural section at Balcony Falls, where the James River passes through the mountain, about fifteen miles S.W. of my line, there is a very interesting exposure of all the divisions here given—similar in relative position, similar in lithological and fossil characters, and having the same general dip.

No. I.—The group, No. I, *a*, as a general rule, has a layer of feldspathic and siliceous conglomerate near the bottom, then

dark shales alternating with sandstones more or less conglomerate. The shales, however, predominate. Next comes a bed (*b*) of very hard sandstone—quartzite; the upper and lower layers of which are more brittle than the main mass lying between them. This is succeeded by a much thicker mass of brown, purple and yellow shales (*c*), with thin beds of brittle sandstones. This mass is extensively disintegrated at the James River pass on both sides, where its thickness is about 550 feet, including a considerable bed of sandstone which at that point seems to separate it into two somewhat distinct divisions. But at Robinson's Gap, and other places, this bed of interstratified sandstone either disappears or becomes very thin. The bed (*d*) is very constant, very hard, and has a jointed structure so deeply marked and so extensive, that the cleavage planes thus developed have sometimes been mistaken for planes of stratification dipping S.E. The division (*e*) consists of shales of much lighter color than those found lower in the series. Some of the beds are decidedly kaolin in character, with numerous scales of mica disseminated through them. Up to this point we find only very faint indications of fossil remains of either plant or animal. A few scolithus borings (in *b* and *d*) are found, but they are rare, in comparison with what are found in (*f*). This (*f*) is the "typical sandstone" of the range, and constitutes the frame-work of what was once a continuous ridge, but is now crossed by numerous gorges, which have divided it into many short ridges and irregular knobs and peaks. It is a hard sandstone of white and light gray color, and jointed structure; and along this and other parts of its range it "exhibts vague, fucoidal and zoophytic impressions on the surface of bedding, together with innumerable markings at right angles to the stratification, penetrating in straight lines to great depths in the rock, and from their frequency and parallelism determining its cleavage in nearly parallel planes. These markings are of a flattened [many of them] cylindrical form, from $\frac{1}{8}$th to $\frac{1}{16}$th of an inch broad, giving the surface of the fractured rock a ribbed appearance, and resembling perforations made in sand which have been subsequently filled up, without destroying the original impression." Such is Professor W. B. Rogers's description of the characters given to this heavy bed of rock by the *Scolithus linearis*. These fossils are so numerous that I recently counted at Balcony Falls about 150 of their extremities projecting on one square foot of surface. This may very properly be called the "Scolithus bed" of this Primordial formation. The thinner beds at the top and bottom disintegrate rapidly. Between this and the first limestone of the valley is a thick mass of ferruginous shales generally much disintegrated and covered with the

debris of sandstone from the adjacent ridges just described. This is (*g*) on the section. It sometimes rises to a considerable height on the slope of the "scolithus bed," especially where the dip is low; and in a few cases, as at Irish Creek, I have found it reaching the crest of the ridge. It is one of the richest repositories of iron ore in Virginia—especially brown hematite—and has valuable beds of manganese, one of which, near Waynesboro', in Augusta county, is at present extensively worked. The ores of the Shenandoah Iron Works of Page county are obtained from this bed of shale. Although it abounds in iron ores, yet it has the peculiar feature of containing a layer of clay so white as to be called "chalk" by the people of the region.

This brings us to the border of the limestones of the valley, and the plane of division between No. I and No. II. Thus we have passed over the Primordial Period. If it has here representatives of both the Acadian and Potsdam epochs (which I doubt) the lowest shales and sandstones must represent the former, and the upper shales and sandstones the latter. For the present, at least, I shall regard the whole as belonging to the Potsdam. The total thickness varies considerably as we ascend the ridges. This is especially conspicuous in the beds of shale, and causes such a decided variation in the dip of the sandstones as to make them present the appearance in many places of segments of broken arches; the dip varying as it does here and at Balcony Falls from 65° at the base to 30° near the upper margin, or outcrop of the beds. This peculiarity has been caused either by an original thinning out of the beds towards their margin before they were upheaved, or by a squeezing out of a portion of their material by the resistance and pressure of the more unyielding beds of sandstone above and below, at the period of upheaval.

The *thrust*, which was doubtless from the Blue Ridge towards the valley, seems to have been more powerful near the base than it was near the summit. Hence the steeper dip below, which has become reversed in the limestones for several miles from the foot of the mountain.

No. II.—The first natural subdivision (*a*) of the valley limestones may with propriety be called the "Hydraulic Formation," inasmuch as it abounds in hydraulic limestones throughout its whole length. It includes, however, several layers of very siliceous and argillaceous limestones separated from one another by beds of brown, bluish and purple shales, and some soft sandstones. The best bed of hydraulic stone is near the bottom of this division, and where it has been quarried for many years, near Balcony Falls, is only about twelve to fifteen feet thick, and dips steeply to the N.W. Where our section

crosses the strata of *a* they are nearly vertical. From this point to the Brushy Hills beyond Lexington, the strata (with one or two local and very limited exceptions), all dip towards the Blue Ridge; and, upon a superficial view of the case, might be supposed to extend beneath it. But examinations of the relative position of the sandstones and limestones at other points in the valley, together with lithological and fossil peculiarities that prove the more recent origin of the limestones, lead to the conclusion that they are *geologically* above the sandstones and shales already described. The several repetitions of the subdivisions of No. II, between the Poplar Hills and North River can be accounted for only upon the hypothesis of plications in the strata caused by pressure on the one side and resistance on the other. We conclude, therefore, that the hydraulic beds (*a*), as originally deposited on the ancient sea-bottom, underlie those of *b*, while these again were overlaid by the beds of *c*. Only occasional fucoid plants, and brachiopod mollusks have been seen in *a*. It seems to be the equivalent of the Calciferous Epoch of New York (3 *a*, Dana).

No. II *b*, embraces a series of heavy beds of dark blue limestones, with some dark brown and yellow shales intervening. A large proportion of the limestone is magnesian (dolomitic), and some beds hydraulic. The oxide of iron abounding in this formation, gives a dark brown color to the soils produced by its disintegration. These are among the best and most durable soils of the valley. The next and upper division (No. II *c*), is characterized lithologically, (1) by having the greater part composed of light blue and bluish-drab colored limestones, with yellow shales interstratified, especially among the lower beds; (2) by one and sometimes two beds of coarse, brown, friable sandstone between layers of light-colored limestones, and (3) by a remarkable bed of *chert* near its upper limit. This hard, flinty, durable rock has so far resisted the force of disintegrating agencies, as to be left as a covering on the faces of many of the limestone hills throughout a large extent of the Great Valley. This chert bed varies in thickness from one to ten feet within the range of a few miles; but it and the brown sandstone lower down serve as well defined land-marks for this whole formation. The brown sandstone has preserved imperfect impressions of several species of brachiopod shells, while in the chert bed are found in some localities large numbers of silicified shells of gasteropod and cephalopod mollusks. This division (*c*) by disintegration yields light clay and sandy or pebbly soils, according to the varying characters of the outcropping strata. These soils are only moderately productive—some of them very poor. Local deposits of limonite ore in this formation have been mined in past years to supply some of the iron furnaces in Augusta county.

The lithological and paleontological characters of this group ˙rocks, as well as its position seem to identify it with the hazy Epoch (3 *c*, Dana).

The dotted lines on the section give an ideal representation f the foldings and inversions to which these rocks were sub- ∝cted when turned up from their original bedding. There as not, of course, the regularity and symmetry in the fold- ıgs that these lines indicate, for there are along the line many vidences of local warpings, fractures, dislocations, etc., that ɔuld not appear on such a section. Several trap-dykes are ɔund protruded through the rocks of No. II, in Augusta and ockingham counties, but none, so far as I know, in Rock- ridge. The Natural Bridge, from which this county takes its ame, is in *b*—being a portion of one of its upper strata span- ing a cañon or gorge, cut through its lower beds to a depth of ıore than 200 feet.*

No. III.—In some respects this group of rocks differs so idely here from its condition in Augusta and Rockingham ɔunties, where Professor W. B. Rogers adopted it as typical ı his earlier Reports, that I feel confident that he then regarded ɔme of the heavy, but quite irregular beds of limestone in the exington basin as a part of No. II, but I am equally confi- ent that he would, upon a more detailed examination, class ıem as Trenton Limestones—base of III.

The lower bed (*a*) of this group is peculiar, as far as I have et observed, to Rockbridge and adjacent portions of Bote- ɔurt and Augusta counties. It has all the appearance of an ld coral reef very much disintegrated, stratified, and subse- uently solidified by the infiltration of carbonate of lime which as given the mass a crystalline texture, and converted it into gray limestone, very compact and admirably adapted for uilding purposes. The bed has well defined horizons both elow, where it is separated from the chert of No. II *c*, by one r two thin layers of light blue limestone; and above, where it s covered with a layer that is shaly in some places and in thers very hard, and full of white veins of calcite and dolo- nite. The upper and lower portions of this coralline bed are quite full of shells as well as fragments of coral; the middle ɔortion is more purely coralline, more compact, and better ıdapted to the architectural purposes to which it is extensively ıpplied; and to the manufacture of lime. The most easterly ıutcrop in this neighborhood is on Hoffman's Run, about one oile S.E. of the town, where the total thickness is about sixty 60) feet. It seems to run out somewhere beneath the syncli- .al fold that forms the Poplar Hills, but appears again on Buf-

* I incline to the belief that this gorge was originally a *crevice* in the strata, ıd subsequently enlarged by erosion—not the result of erosion alone; the arch ıving escaped fracture when the crevice was produced.

falo Creek, six miles to the S.W. N.W. of Lexington the outcrop of this bed is finely displayed along some parts of the base of Brushy Hills, and especially on the North River, a mile above the town bridge, where it forms a nearly vertical cliff, exposing its entire thickness, which at this point is about 150 feet. This thickness is preserved in the synclinal between Brushy Hills and House Mountain, and also at other points where it appears below (*b*) the thicker mass of Trenton Limestone.

No. III, *b*, crops out extensively on both sides of Poplar Hills, forms the whole of the synclinal over which Lexington stands,* and is the foundation rock of the House Mountains, around the base of which it may be seen cropping out on all sides. The general position here is horizontal, or nearly so, with some local curves. Northwest of Kerr's Creek valley it disappears beneath the North Mountain.

The general structure of *b* differs very widely from all the lower limestones—the beds here, except some of the lowest, being thin layers of argillaceous limestones, with interstratified shales. Near the base of *b*, especially along its S.E. portion, underlying the Poplar Hills, we find a bed of very compact blue limestone irregularly bedded and very full of infiltrated veins; but, as we ascend, the rocks become more and more argillaceous, with the beds of shale becoming more numerous; and finally, as may be seen on House Mountain, after passing upward through a thickness of about 650 feet, the shale becomes predominant, but still contains some thin beds of limestone remarkable for the profusion of fossil shells, crinoids and coral found in them. There is no well-defined horizon here, between what is represented on the section as *b* and *c*, but the former seems in general characters to be the equivalent of the Trenton limestone, and the latter of the Cincinnati (Hudson) shales. It is about 750 feet thick.

Remark.—I have not seen any outcrop of the division, *a*, of No. III in Augusta county northeast of Staunton, nor have I seen it at all in Rockingham. If its equivalent appears in that part of the valley, it is under quite different lithological and fossil peculiarities. I might say almost as much in regard to *b*; for limestone beds form a very inconspicuous part of III, from Staunton (or rather a point S.E. of that place) to a point in Rockingham county, where it passes under IV in the Massanutton range of mountains.

"FAULT."—This seems to be the proper place for directing attention to the "Fault," the line of which passes in front (S.E.) of the House Mountain. It is easily traced for several miles

* This synclinal is really *double*—having a line of uplift running through it, but the scale of the section would not admit its insertion. There are also some local irregularities here.

ways from one line of section. The lower and older of No. II are found (in their own normal order) overly-ıe newer of No. III *b*, which dip beneath them. At a ·er of points between Kerr's Creek and Collier's Creek, onsiderable streams that run out from the N. Mountain : opposite extremities of the House Mountain ridges, this ŋg of the newer under the older rocks may be seen along of very considerable regularity.

r general description has now extended to the horizon ·en the Lower and Upper Silurian.

IV, the equivalent of the Medina group, is composed of durable sandstones that are the chief mountain-making along the northwest margin of the valley, and through-belt of twenty or twenty-five miles wide, parallel with it. .y be represented under three subdivisions. The lower f which (*a*), is a very hard, light gray, sometimes white, tone, distinctly conglomerate in many places, and so le as to present long lines of precipices where the strata ›ut on the faces of the mountains. The middle member this group is a dark brownish purple sandstone with beds erstratified shales of the same color. Shells in the sand-, and fucoids in the shales, are conspicuous features of .ivision. A third member (*c*) is much lighter in color ›, but darker than *a*. Some of the harder layers have a ;h hue, while the softer and more brittle, especially near p, where they border on No. V, are brown and yellowish ı in color. While this group, as it appears on the two ı of House Mountain, rests upon a nearly horizontal base, ; North Mountain its position is changed to that of a northwest dip.

; general pressure that acted from the Blue Ridge side of ·alley towards the northwest, seems to have lifted the ; Mountain ridges somewhat above what was the original of the surrounding region, and, at the same time, to have n off and pushed back the edges that now form the crest ›rth Mountain. But while the section represents the gen-;sult, it will be found on examination, that there are a ·er of local and limited irregularities in the form of con-ns and fractures that could not be exhibited on a scale ıenting so much space within so short a limit. So, also, it ere, apparently, a greater degree of symmetry on the sur-than the denuding forces to which it has been subjected, given it. But in this regard, also, the irregularities are ımerous and limited to find a place on the section.

e strata of this group all thin off as they extend farther ·ds the interior basin of the coal regions. They also vary ı in thickness where they crop out along the margin of the

valley. What now caps House Mountain is about three hundred and sixty feet thick, while, at the highest point, it may have lost one hundred feet or more of its original height. On the Warm Springs Mountain, in Bath County, twenty miles farther towards the great Appalachian coal basin, the thickness is very perceptibly less. At Panther Gap, two or three miles west of Goshen, where the Chesapeake and Ohio Railroad passes through Mill Mountain, a very complete section of No. IV is displayed as a folded and inverted anticlinal—inverted towards the northwest so that the higher strata of V, VI and VII, seem to underlie IV.

No. V is in most places, in this part of the Appalachians, a bed of shales and brittle, shaly sandstones. In the upper part the shales predominate and have some thin bands of limestone. Valuable iron ores, some of them highly fossiliferous, abound in this formation. The development of this group is not extensive where our line of section cuts it. This seems to be the only representative we have here of the Clinton and Niagara epochs (5*b*, and 5*c*, Dana).

No. VI is not actually visible where the section passes, but its outcrops on both sides of the same valley, at points not very remote, seem to justify the hypothesis that it actually exists at this point though concealed from view by the debris of sandstone and clay from the adjacent mountain. In this part of the Appalachian range it consists almost entirely of limestones that are remarkable for the profusion of fossil coral, shells and encrinites found in them. The stone is pure enough in some of its beds to make good lime, and firm enough to make good building material for houses, railroad masonry, etc. In the prolongation of the same mountain valley, in which our section terminates, this formation is largely developed along the line of the Chesapeake and Ohio Railroad, between Goshen and Buffalo Gap. At Craigsville, nine miles northeast of Goshen, it affords an extensive quarry of beautiful encrinal marble. It is the Helderberg Limestone. (7 Dana.)

No. VII is a singular bed of brownish and greenish-gray sandstone of coarse texture, easily broken, and in many places disintegrates readily under the weather. In other localities it is more durable, forms rather low flat arches, and when cut through by streams presents precipitous exposures. It is said to have valuable deposits of iron ore at several points in Virginia. Great numbers of fossil brachiopods, especially *Spirifer arenosus* and *Rensselæria ovoides*, are found in it everywhere.

This is a remarkably well defined formation, readily distinguished by its lithological peculiarities and its fossil remains. It is cut by the Chesapeake and Ohio Railroad at several places between Buffalo Gap and Goshen. On the turnpike leading

Millboro to the Warm Springs, about three miles from the n at which the stage coaches leave the railroad, this forma- nay be seen as an anticlinal arch, spanning the lower lime- of VI, in which the famous "Blowing Cave" of Bath ty is situated. Here the Calfpasture River has cut gh a ridge and given a natural section along the base of ı the stage-road passes, and where the Oriskany and Hel- rg formations are well exposed, and, together with the ing Cave, present points of considerable scientific interest. , also, the meeting of the Oriskany, the upper member of ilurian, with the Marcellus (?) shales, at the base of the nian, may be distinctly observed on both sides of the

e following table exhibits a comparison of the subdivis- n this portion of the Virginia valley, with the periods and ıs in Professor Dana's Manual:

ian rocks of the Great Valley of Virginia with their sub-divisions, compared with equivalent epochs of Dana's Manual, p. 142.

Periods.		Epochs.	Rogers' Series.		Virginia Valley Sub-divisions.
skany.	8	Oriskany,	No. VII.		Spirifer Sandstone.
Helderberg.	7	L. Helderberg.	No. VI.		Encrinal Limestone.
ina.	6	Salina.	No. V.	*c*	Calcareous Shales.
ıgara.	5*c*	Niagara.		*b*	Ferriferous Shales.
	5*b*	Clinton.		*a*	Shaly Sandstones.
			No. IV.	*c*	Upper Sand-rock.
	5*a*	Medina.		*b*	Purple Shale and Sandstone.
				a	Conglomerate.
ınton.	4*c*	Hudson Riv.	No. III.	*c*	House Mt. Shales.
	4*b*	Utica.			
	4*a*	Trenton.		*b*	Lexington Limestones.
				a	Coraline Limestones.
ıadian.	3*c*	Chazy.	No. II.	*c*	Cherty Limestones.
	3*b*	Quebec.		*b*	Dolomitic Limestones.
	3*a*	Calciferous.		*a*	Hydraulic Limestones.
imordial or Cambrian.			No. I.	*g*	Iron-bearing Shales.
	2*b*	Potsdam.		*f*	Scolithus Sandstones.
				e	Kaolin Shales.
				d	Middle Sandstones.
	5*a*	Acadian.		*c*	Middle Shales.
				b	Lower Sandstones.
				a	Lower Shales.
rchæan.		Archæan.	Meta-morphic.	*c*	Slates and Syenite Gneiss.
				b	Bedded Syenite.
				a	Lower Slates.
			Igneous.	*E*	Eruptive Syenite.

ART. III.—*On a new form of Spectrometer, and on the distribution of the intensity of Light in the Spectrum;* by JOHN WILLIAM DRAPER, M.D., President of the Faculty of Science in the University of New York.

I HAVE invented a spectrometer which I think will open a new and interesting field to those who are engaged in spectrum analysis.

The ordinary spectroscope is occupied with the frequency of ether-vibrations or wave lengths. This, which I am about to describe, has a different function. It deals with the intensity or brilliancy of light.

It depends on the well known optical principle that a light becomes invisible when it is in presence of another light about sixty-four times more brilliant.

In some researches, published by me in 1847, on the production of light by heat or the incandescence of bodies, I used this method as a photometer, and became sensible of its value. The memoir in which those experiments are related may be found in my recently published "Scientific Memoirs," page 23.

Having also published in 1872 a memoir on the distribution of heat in the prismatic spectrum, and shown that the cause of its increasing intensity from the more to the less refrangible regions is due to the compression of the colored spaces that correspondingly takes place, owing to the action of the prism itself, but having failed to obtain satisfactory measures in the case of the diffraction spectrum, in which such compression or condensation does not occur, I was led to reflect whether better success might not be secured by attempting to measure the relative intensity or distribution of the light.

Admitting what is commonly received as true, that the yellow is the brightest of the colored spectrum spaces, and that the luminous intensity diminishes from that in both directions, above and below, I supposed that if such a spectrum was brought in presence of an extraneous light, the illuminating power of which could be varied at pleasure, that after the red and the orange on one side, and the green, blue, indigo and violet, on the other, had been extinguished, the yellow would still remain in the midst of the surrounding illumination. On making the experiment it turned out differently.

For the sake of clearness of description I will call this extraneous light, from the function it has to discharge, *the extinguishing light.*

There are many different plans by which the principle above indicated may be carried into practical effect. Several of these I have tried, and have found the following a convenient one.

Remove from the common three-tubed spectroscope its scale tube, and place against the aperture into which it was screwed a piece of glass, ground on both sides. In front of this arrange an ordinary gas light, attached to a flexible tube, so that its distance from the ground glass may be varied at pleasure. On looking through the telescope tube, the field of view will be uniformly illuminated, this being the use of the ground glass. The brilliancy of the field depends on the distance of the gas light, according to the ordinary photometric law.

1st. *Case of the prismatic or dispersion spectrum.*—If the extinguishing light be for the moment put out, and in the proper place before the slit tube the *luminous* flame of the Bunsen burner that accompanies the apparatus be arranged, on looking through the telescope a spectrum of that luminous flame will of course be seen. The slit itself should be very narrow, so that the spectrum may not be too bright.

Now let the extinguishing flame be placed before the ground glass, and a spectrum is seen in the midst of a field of light, the brilliancy of which can be varied at pleasure. If the extinguishing flame be at a suitable distance, the whole spectrum may be discerned. As that distance is shortened, first the violet, and then the other more refrangible colors in their descending order disappear, and at length in the steadily increasing effulgence the red alone remains. The yellow never stands out conspicuously as might have been expected.

This is scarcely consistent with the assertion that the yellow is the brightest of the rays. The red is plainly perceptible long after the yellow has gone. There is a greenish tint emitted by gas-light that disappears a little previously to the extinction of the red.

From these observations I think that the luminous intensity of the colored spaces has a relation to the compression or condensation that the prism is impressing upon them. It may be that, properly considered, the intrinsic intensity of the light is the same for all. In this we must always bear in mind the physiological peculiarities of the eye.

The foregoing statement is perhaps sufficiently explicit to enable any one to verify the facts. I may, however, mention some improvements in the apparatus, which experience has led me to adopt.

The intensity of the extinguishing light may be insufficient to obliterate the spectrum, even though the slit be closely narrowed. How then may the intensity of the spectrum be diminished, and that of the extinguishing light be simultaneously increased? I accomplished this by depositing on that face of the prism which acts as a reflector an *excessively* thin film of silver. This, though it was transparent to the transmitted

rays increased very greatly by its metallic reflection the extinguishing ones. I could not see any difference between the spectrum of the light that had come through this film and that before the face was silvered, but the reflected light was incomparably more brilliant. The complete obliteration of the entire spectrum presented now no difficulty.

Nothing need be said about collateral contrivances, which would suggest themselves to any one: A strip of wood a metre long, and bearing divisions served to keep the extinguishing lamp in the proper direction as regards the ground glass, and indicated its distance. I may add, however, that satisfactory observations can be made very conveniently by keeping the extinguishing flame at a constant distance, and varying its intensity by opening or closing its stop-cock. This avoids the trouble arising from moving the flame. In one instrument I caused an index attached to the head of the stop-cock to move over a graduated scale, and so ascertained how much it was opened. This, though permitting of pleasant working, had not the exactness of the method of distances.

Such are the results obtained from the prismatic dispersion of gas-light. I completed this part of the investigation by an examination of sunlight. For this purpose I resorted to the foregoing principle, introducing a beam of sunlight, reflected from a heliostat through a slit. The spectrum of this was thrown upon a paper screen, so placed that by opening or closing an adjacent window-shutter the light of the sky in greater or less quantity could fall upon the paper, and act as an extinguisher. When the shutter was fully opened the spectrum was quite obliterated, and on gradually closing it so as to diminish the extinguishing light, the red region first came into view, the other colors following in the order of their refrangibility, the extreme violet appearing last. On reversing the movement of the shutter the colors disappeared in the reverse order, the red disappearing last.

At the moment when the red was approaching extinction there always existed on its more refrangible side a gleam of grayish-green light. It was in the position of that greenish gleam which appeared as I have described when gas-light was examined. Its color recalled to my mind the faint greenish-gray light I had seen when a strip of platinum is ignited by a feeble electric current, as described in my memoir of 1847, above referred to.

Subsequently I constructed a camera having two apertures in its front. Through one of them, by a suitable arrangement of a heliostat, slit, direct-vision prism, and convex lens, a solar spectrum was formed on the ground glass. Through the second aperture, which was about an inch square, covered with a

ground on both faces, an extinguishing beam of sunlight
l. This ground glass served to disseminate the extin-
ing light uniformly over the spectrum. I could regulate
ower of this light by varying the size of the aperture
gh which it came by means of a slide.
is needless to give details of the results obtained by this
iment. They were identical with those described in the
oing paragraphs.
might be supposed that the irrationality of dispersion of dif-
t prisms would influence the results perceptibly. Accord-
, I tried prisms of different kinds of glass and other trans-
it substances, but could not find that this was the case. In
ie extinction began in the violet and ended in the red.
r did there seem to be any difference when the effect was
ed by different eyes. To persons, irrespective of age or
ondition of their sight, the extinction took place in the
manner. I had not an opportunity of examination in a
of color-blindness.

Case of the Grating or Diffraction Spectrum.—If the cause
e increasing intensity of light in the prismatic spectrum
the more to the less refrangible region be the compression
ised by the prism on the colored spaces, increasing as the
igibility is less, we ought not to find any such peculiarity
e diffraction spectrum. In this the colored spaces are
ged uniformly and equably in the order of their wave-
hs. An extinguishing light ought to obliterate them all
e same moment.
ving modified the common spectroscope by taking away
rk box so that the slit tube and telescope tube could be set
y required angular position, I put in the place of its prism
ss grating inclined at forty-five degrees to rays coming in
gh the slit. The ruled side of the grating was presented to
it. Now when the extinguishing flame was properly placed
e the ground glass, the plane side of the grating reflected its
down the telescope tube. In this, as in the former case, the
rum was seen in the midst of a field of light, the intensity of
h could be varied by varying the distance of the extinguish-
lame, or by varying the opening of its stop-cock. This
needs no reënforcement by increasing the reflecting power
ie back face of the grating, these spectra being much more
e than that given by a prism, and the unassisted light
g quite able to extinguish them.
s the glass grating I was using gave its two series of
ra of unequal brightness, I selected the most brilliant,
in it used the spectrum of the first order. I saw, not with-
pleasure, that as the force of the extinguishing illumin-
increased, all the colored spaces yielded apparently in an
l manner, and disappeared at the same moment. Some-

times, however, there seemed to be a very slight difference in favor of the red. On diminishing the illumination all the colors came into view apparently at the same time. This spectrum gives a better opportunity than the prismatic for observations on the yellow space, which by being uncompressed, exposes a wider surface to view. This yellow space showed no superiority in resisting extinction over the other colors.

But as gas-light, compared with sunlight, is deficient in the more refrangible rays, I repeated the examination of the latter, as I had previously done for the prismatic spectrum, modifying the apparatus so as to use a grating in the place of the prism. The observations in this case of sun-light were quite as satisfactory as those in which gas-light had been used.

General conclusions.—1st. In the prismatic spectrum the luminous intensity increases from the more to the less refrangible spaces, its maximum being not in the yellow but in the red. This is due to the action of the prism, which narrows, and as it were, condenses the colored spaces more and more as we pass toward the red, increasing the intensity of the light as it does that of the heat.

2d. In the grating, or diffraction spectrum, the luminous intensity is equal in all the visible regions, all the colors being simultaneously obliterated by an extinguishing light.

It must, however, be borne in mind that these conclusions should be taken in connection with the physiological action of the eye. Owing in part to the imperfect transparency of its media, and partly to the inability of its nervous mechanism to transmit waves of certain frequency to the brain, the spectrum does not begin and end sharply, as to a perfect eye a perfect spectrum ought to do.

There are, hence, two causes which must not be overlooked in these observations. 1st. The physiological peculiarity of the eye, which gives to each end of the spectrum the aspect of gradually fading away. 2d. In the case of solar-light the absorptive action of the atmosphere, which is chiefly exerted on the more refrangible rays.

I think, bearing in mind the correlation of light and heat, both being corresponding manifestations of the same vibratory movement in the ether, that these results substantiate those I published in 1872, on the distribution of heat in the spectrum; and that as the different colored spaces are equally luminous, so they are equally warm.

I have made some attempts to compare with each other the luminous intensity of the bright lines in various spectra, especially those emitted by a strontium flame, but not being able to continue these researches at present, I have postponed them to a more favorable opportunity.

University of New York, May 5th, 1879.

ART. IV.—*On the Extinct Volcanoes about Lake Mono, and their relation to the Glacial Drift;* by JOSEPH LECONTE.

[Read before the National Academy of Sciences, April 16, 1879.]

IN 1870, and again in 1872, in company with a party of students and graduates of the University of California, I visited the Mono region. But on both occasions my attention being specially directed to the study of the ancient glaciers, I examined the volcanoes only somewhat cursorily. In 1875 with a similar party I again visited the same region, and this time remained longer and examined more carefully, though on account of an unfortunate accident, not so long or so carefully as I desired. I have put off from year to year the publication of the results of my observations in the hope of again visiting the region and settling some doubtful points which still remained. There seems now, however, little likelihood that I shall ever be able to carry out my intention, for other questions of still greater interest have in the meantime engaged my attention. I will therefore no longer withhold my imperfect observations, hoping that they will be corrected and extended by others.

General description of the region.—Eastern slope of the Sierra.—As already explained in previous papers,* the general form of the Sierra is that of a great wave ready to break on its eastern side. It rises from the San Joaquin plains by a gentle slope which extends 50 to 60 miles, reaches a crest 13,000 feet high, then plunges downward by a slope so steep that it reaches the plains of Mono 6000 ft. above sea level, in five or six miles. In glacial times, long, complicated glaciers with many tributaries occupied the western slope, while on the east, comparatively short simple glaciers came down in parallel streams and ran far out on the level plain and into the swollen waters of Lake Mono, which, then nearly 700 feet above its present level and far beyond its present limits, washed against the base of the Sierra itself. There can be no doubt that these glaciers formed icebergs which floated on the surface of the great inland sea and dropped débris over its bottom.

The Plains.—Surrounding Lake Mono and sloping imperceptibly to its surface, is a nearly level desert plain, covered with volcanic sand interspersed with fragments of pumice and obsidian, and overgrown with sage-brush (*Artemisia tridentata*). It is undoubtedly an old lake bottom, subsequently covered with volcanic ashes. The dreary prospect of this desert is relieved by the magnificent irregular Sierra wall trenched with deep cañons; by long parallel moraine ridges stretching like arms from the mouth of each cañon, five or six miles out on

* This Journal, III, v, 325, 1873; x, 126, 1875; xvi, 95, 1878.

the level plain, and bounding the pathways of ancient glaciers; by a fine cluster of recently extinct volcanic cones fifteen to twenty in number and very perfect in shape, and finally by the bright waves of the lake studded with picturesque islands.

Moraines.—Some of the parallel moraines which form so conspicuous a feature of the scene, especially those of Bloody cañon, I have already described.* From the top of any of the higher volcanic cones, many others may be seen stretching out upon the plain. These moraine ridges average 300 to 400 feet in height and five to six miles in length, but some of them, especially those at the head of Rush Creek, are much higher. The view of glacial moraines here presented is incomparably the finest I have ever seen.

Lake.—Lake Mono is a fine sheet 14 by 10 miles in extent. There being no outlet the waters are of course saline. It is essentially a strong solution of sodium carbonate, with smaller proportions of lime carbonate, common salt and borax. To the taste it is simply a concentrated solution of carbonate of soda. While camping on its margin we found its powerful detergent property very useful in clothes-washing. The mineral contents are probably partly the concentrated leachings from the volcanic rocks which cover the whole plains—the alkaline silicates of these rocks being changed into alkaline carbonates by carbonic acid of the air—and partly contributed by springs which issue in many places from the bottom and around the margins of the Lake, and were probably more numerous and active in former times. In any case, the lake waters are now but the concentrated residues of a much larger body of water, as plainly shown by the terraces to be presently described. During the process of concentration the less soluble lime carbonate has been deposited in strange irregular masses of calcareous tufa. These curious fungoid and coralloid masses, some of them six to ten feet in height, stand up thickly on the level shores and in the shallow marginal waters of the lake. At a distance they look like the half-submerged stumps of a forest of gigantic trees. This carbonate of lime deposit is evidently identical with the thinolite deposit described by King† as occurring in such immense quantities about the residual lakes of the Nevada basin farther north, and which as he shows is a pseudomorph of carbonate of lime after Gay-Lussite. The conditions under which the deposit took place about Mono are probably, however, slightly different from those in Nevada, and I believe throw much light on the general question of thinolite deposits. It deserves careful study and I hope to take it up in a subsequent paper. Farther east, near Columbus, Nevada, in the region of the dried-up lakes left at the extreme southern exten-

* This Journal, III, v, 325. † Geol. Exploration 40th Parallel, i, 508, and seq.

of King's ancient lake *Lahontan*, occur remarkable depos·
›f ulexite (soda-lime borate) which also deserve separate
y.
›rraces.—I have already mentioned the terraces about Lake
o. Several of these are very distinct and traceable all
nd the lake. But they are seen in greatest number and
; distinctly on the west side, where the lake approaches the
·a and the hills rise abruptly from the lake-level. Five or
nay here be counted, rising one above the other like level
hes, the highest being, according to Whitney, 680 ft. high.
›e terraces are undoubtedly the marks of old lake levels,
show not only a former greater depth but also a much
ter extent of the lake waters. The highest level traced
.t the lake would reach the moraines at the foot of the
·a, extend beyond the plains on every side, and enclose an
many times greater than the present lake-area. There can
o doubt therefore that the great glaciers of that time ran
the lake and formed icebergs.
lands.—Near the center of the lake there is a group of vol-
; islands in direct line with the groups of volcanic cones on
plains to the south and doubtless a continuation of the
› line of volcanic activity. The largest of these islands is
ıt 2½·miles long, a mile wide and about 800 feet high. It
mposed mainly of extremely fine, whitish material, beauti-
· and very finely laminated, the differently colored laminæ
g very distinct and scarcely thicker than cardboard. This
·rial is spoken of by Whitney* as volcanic ashes. Under
nicroscope it proves to be composed wholly of *diatom shells*
only an occasional grain of sharp sand. There is no doubt
:fore that it was deposited very slowly in calm waters, in
niddle of the lake and beyond the reach of detritus. The
ification is mostly horizontal; only in two or three places
·e the deeper strata are exposed on the cliffs by the action
aves, I observed a slight dip, and in one place a gentle but
nct *anticline*, showing a quiet upheaval of the whole mass,
think, by volcanic forces. In the highest parts of the
.d, the soft, horizontally-laminated earth is sculptured by
ion into sharp pinnacles and turrets like bad-land structure
small scale. On the eastern portion of the island a con-
rable area of black basaltic rock is exposed, but this is no
re more than 50 feet high. Where the diatomaceous earth
es in contact with the basalt, the former always overlies
latter in undisturbed horizontal layers. I conclude there-
that the basalt preceded the formation of the diatomaceous
, was once entirely covered by the latter, and was subse-
ıtly exposed by erosion.

* Geol. Survey of California, i, 453.

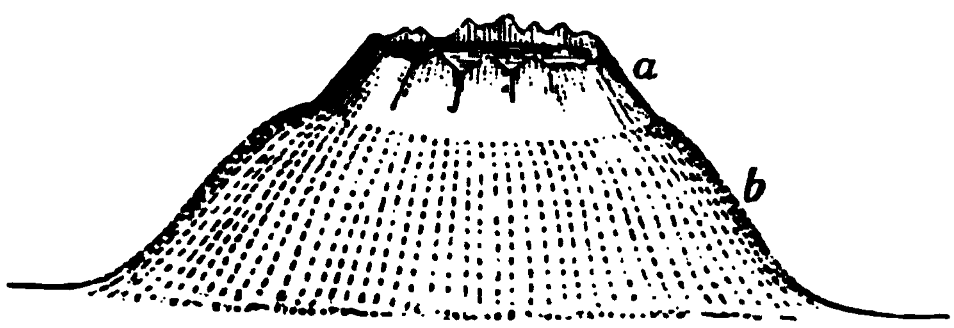
Steam and boiling water issue in many places in this rocky portion of the island and in the shallow water in the vicinity. I observed also in the earthy portion crater-like depressions, containing a little saline water, which were probably produced by similar fumarole action now extinct. According to Whitney (p. 453) two distinct true craters occur in the basalt on the northeast portion of the island; but these I did not see.

The other and much smaller islands I did not have time to visit, but according to Whitney, they are wholly basaltic, and the largest of them is 300 feet high, and is a well-defined volcanic cone.

The general conclusion, at which I arrived from my examination of the largest island, was that the basaltic portion was first formed at the bottom of the lake, or else subsequently submerged; then the diatomaceous mud was deposited, covering it up completely; then the fine mud-bottom was raised into an anticline and exposed as an island by the fall of the lake level, and finally erosion sculptured the whole, and in part exposed the underlying basalt.

Volcanoes on the Plains.—We have already alluded to a conspicuous group of volcanic cones situated on the level plain south of the lake. These are twenty or thirty in number, extending in a line from near the margin of the lake to a distance of ten to fifteen miles, and vary in height from 200 to 2,700 feet above the plain. Partly from the recency of their

1.



extinction, and partly from the small rainfall of the region, they are, some of them, as perfect in form as if they were still in action. A good general view of these is given by Whitney in his account of this region. The typical form of the more perfect is shown in fig. 1, which, though intended only as a diagram, is yet a tolerably correct outline of the highest and most perfect. The upper part *a* is a light-colored pumiceous lava, and the lower part *b* is covered with sand of the same.

In many cases I observed a very perfect cone-and-rampart structure, such as is known to be produced by great eruptions, followed by smaller ones; or perhaps in some cases by an engulfment of the crater into the base of the cone. The most perfect example of this kind is found in a small and easily accessible cone, not far from the lake. Fig. 2 is an ideal

ection and half perspective view of this cone. It consists of a low sand cone about 200 feet high, with a perfect circular crater one and a half to two miles in circumference, from the center of which rises a trachytic cone and crater of much smaller dimensions, to about the same height. From the

2.

battered condition of the inner cone, Mr. Muir suggested to me the possibility of the engulfment of the upper rocky portion into the lower sandy portion of a once much higher cone. But, in many other cases observed, this explanation is evidently untenable; for in some cases we found several small cones surrounded by one rampart. Such could only be formed by successive eruptions.

The material erupted by these volcanoes is in some cases basalt, but by far the largest amount consists of feldspathic slags, pumice and pumiceous sands and ashes. The whole plains of Mono are covered to a depth of many feet with a nearly white volcanic sand, mingled with fragments of pumice and obsidian.

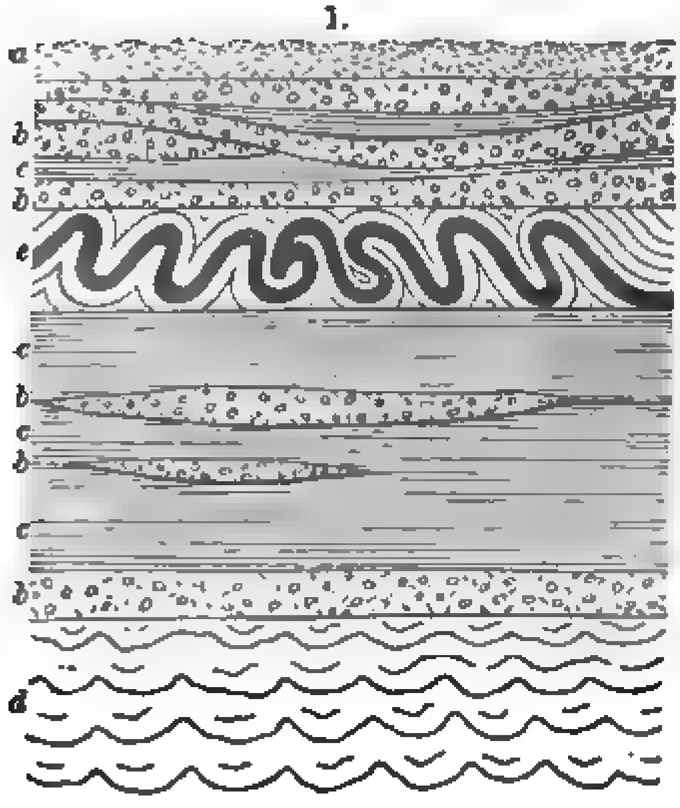
Age of the Mono Volcanoes.—There is abundant evidence that these volcanoes have been active, and therefore that they assumed their present forms since the epoch of great separate glaciers in this region (Champlain). Whether they also existed and erupted previously is perhaps doubtful though probable. The evidences of the extreme recency of the eruptions, which determined their present forms, are as follows:

1. We have already shown the splendid scale on which glaciers were once developed in this region. We have already given reasons for thinking that they ran down the Sierra, out on the plains and into the lake, and produced icebergs there. It is impossible that the volcanic cones, if they then existed, could have escaped the powerful action of ice, and the equally powerful action of other meteoric agencies, so characteristic of that epoch, which must have entirely destroyed their form. The remarkable perfection of their conical forms and of their craters is therefore strongly presumptive if not demonstrative, of the fact of their eruption since the disappearance of the glaciers.

2. All the streams, which run from the Sierra into Lake Mono, cut into the level plains 100 to 150 feet deep. Fine sections of the materials of the plains are thus exposed. Fig. 3 is the upper portion of such a section about eighty feet perpen-

dicular. The lower portion of the cliff, being covered up by talus, is not represented. It is seen that nearly the whole is an ordinary modified drift, composed of irregularly stratified sands and clays, *cc*, intermingled with layers of pebbles and gravel, *bb*. But there are other parts that deserve more special notice. The stratum *e* is a fine light-colored clay, through which runs a deep chocolate-brown lamina scrolled in the most complex and beautiful pattern; the stratum *d* is also strongly crumpled. This crumpling and scrolling of the strata could have been produced only by a glacier advancing on a bed of stratified clay, or else by the pushing of icebergs on a stratified lake bottom. I suppose the whole formation except *a* to have been produced by an alternately advancing and retreating glacier; now retreating and dropping material, to be carried and deposited by the river which flowed from its snout, now advancing and crumpling the finer material of the lake bottom. It may be difficult to explain the details of the process, but I think it will not be doubted that the whole is a distinctly marked drift-deposit. Many other similar sections were observed; some of which were 150 feet thick.

1.



a = unstratified volcanic sand.
bb = pebble and gravel.
cc = fine sand and clay stratified.
d = strata crumpled by moving strata.
e = strata scrolled by same agency.

Now covering everywhere this undoubted glacial material is found a layer of loose, unstratified volcanic sand and pumice, *a*, which has evidently never been touched by the action of water. It is a pure eolian drift. In the section it is about three feet thick, but it is really much thicker, as it thins off on the margin of the perpendicular cliff by falling, and thus contributes to the talus at its base. It is evident that the whole material of the section was deposited during glacial times, except *a*, which was drifted over the bared lake bottom since that time. But judging from the immense quantity of this loose material, covering as it does the whole plain many feet deep, it seems impossible that it is the mere result of disintegration of the vol-

cones in recent times. I suppose, therefore, that it is the
of sand and ash eruptions since the recession of the lake
s.

We have already described the material of the largest
l as being composed wholly, except a portion of the eastern
of a fine infusorial earth, horizontally stratified with
æ of slightly different colors, so thin as to give specimens
nost agate-like beauty. This material was evidently depos-
ı the middle and deepest part of the lake, beyond the reach
ırser sediments, at a time when the place of the island was
lake bottom. Now, that this occurred during or after
ɔoch of great glaciers, is demonstrated by the fact that
red sparsely through this fine laminated material, and
on its surface, having been washed out by erosion, I found
bowlders, both worn and angular, of Sierra granite and
and also of obsidian. These could have been brought
only by the agency of floating ice, either as icebergs or as
ice. If by icebergs, of course during the epoch of great
rs; if by shore ice, either during that time or still later,
anifestly the bowlders were brought down to the shore
the Sierra during that time. It is evident, therefore, that
:ratified mud was formed and the bowlders were dropped
g the period of great glaciers or later. But still later the
itself was upheaved by volcanic action, as shown by the
inal position of the strata at the base, and by the solfa-
ıction still going on. The formation of this island I sup-
to have been coincident with the last eruptions of the
ɔoes on the plains.

Within the craters of several of the volcanic cones on the
, I found pebbles and angular fragments of granite of a
iar reddish color from the presence of a rose-colored feld-
Whitney observed the same, and accounts for them in
llowing manner: They could not, he thinks, have been
ht by glaciers or by water, for this is inconsistent with
:rfect shape of the cones. He rightly concludes therefore
hey must have been ejected from the volcanoes. But if so,
ɿs, "*they must have been torn off from the underlying granite,
h which the eruptive matter has forced its way, as is seen
ɔhere in the Sierra.*"* On the contrary, I account for them
'holly different way. The fragments which I saw were
of them angular—true; but *most of them were well-worn*
. There is not the slightest doubt that *these were pebbles
drift-layer which everywhere underlies the loose sand of the*
The eruptive forces broke through this drift-layer, and
ected pebbles fell back into the crater. They demon-
that the cones and craters, where they are found, not only

* Geol. Survey of Cal. vol. i, p. 455.

erupted, but *were wholly formed*, after the epoch of the pebble drift.

I think, therefore, there can be no doubt that all of these volcanoes erupted, and many of them were wholly formed after the epoch of great glaciers (Champlain). Whether any of them preceded that epoch is doubtful. I have never seen any undoubted evidence that they did. If the bowlders found on the island were carried there by icebergs, then volcanic action preceded the epoch of icebergs, for many of the fragments are volcanic; but they may have been carried by shore ice at a later time. Again, I believe the rocky part of the island is older than the sedimentary part, for the latter seems to have been deposited on the former. If the sedimentation was Champlain, then the rocky part was probably pre-glacial; but the sedimentation may have been later.

Sequence of Events.—Assuming that the island strata belong to the epoch of great glaciers, then the order of events was something like this:

1. Volcanic eruptions on the plains producing obsidian, fragments of which were afterwards carried by ice and dropped in mid-lake. At the same time also, the basaltic part of the islands was formed.

2. Then followed the period of great glaciers and flooded lakes, or Champlain epoch. The lake was nearly 700 feet higher than now. Its waters covered the whole plains and washed against the Sierra; and glaciers from this range ran far into the lake and formed icebergs, which floated over its surface and dropped rock-fragments over its fine mud bottom.

3. Volcanic forces, acting quietly like the solfataras and fumaroles still existing, heaved up the stratified mud-bottom of the mid-lake into a gentle mound with quaquaversal dip of the strata, but not rising to the surface. Coincident with this were the eruptions of the plains volcanoes.

4. The lake then dried away gradually to its present level, leaving the terraces as its old flood-marks, and exposing the rounded mud-island; and erosive agents then sculptured this into its present turreted form and cut away its margin to its present limits, and exposed the mud-covered older basaltic part.

Lake rising again.—The existence of salt and alkaline lakes shows an extreme dryness of climate. But the climate of the desert region has not always been dry. During the Champlain epoch the interior plains were covered with immense sheets of water, of which the present saline lakes are the isolated residues. Gilbert has shown that at that time Great Salt Lake contained 400 times as much water as now, and that it drained northward through the Snake and Columbia Rivers into the

: ocean. King has shown that the Nevada basin was at me time occupied by a vast irregular sheet of nearly extent, stretching southward as far as Columbus, Nevada. iid, Winnemucca, Carson, Humboldt, and Walker Lakes, : concentrated residues of this great lake. Lake Mono also, ive seen, at the same time, was a great sheet of water, er connected with the other or not is not known. There ен therefore an increasing dryness of climate in that re- since the Champlain. Is it still progressing, or has it :d its maximum? This is an important question for the : States.

m my observations on Lake Mono, I have no doubt that el, at the time of my visit, was rising and had been rising 1 or fifteen years. The evidence is as follows: Around ırgin of the lake I found everywhere old fences of sheep : and old trails submerged many feet deep. While visit- e island I found the vegetation of the island, sage brush *nisia tridentata*), and grease wood (*Sarcobatus vermicu-* submerged in five feet of water, and of course killed. ents about the lake state that the waters have risen ten to : feet in ten or fifteen years. I might be disposed to these observations if the same phenomena had not been ved in other lakes in the same dry region. Salt Lake is n to have risen ten to fourteen feet in twenty five years ıbmerged large tracts on its flat margins, and the water by sis is far less salt than formerly. Pyramid Lake, accord- King, has risen nine feet, and Winnemucca Lake twenty- et in only four years—1867–1871. The same is said to e of Walker Lake and of Owen Lake.

: cause of this is evidently increase of rain-fall and snow- chiefly the latter. In this connection it may be well to on an additional evidence of increasing snow-fall in the . I have in a previous paper† drawn attention to a mov- iow-field, or rather an imperfect *glacier*, occupying the cirque at the top of Mount Lyell, the feeble remnant of reat Tuolumne glacier of glacial times. At the foot of *lacieret* there is as perfect a terminal moraine as ever was It is a crescentic pile of rock fragments twenty feet high, eet wide at base, and about a mile long. The fragments brought down by the moving ice from the vertical cliffs : cirque. Many similar fragments are seen lying on the r on their way to the moraine, and in various stages of ce. Now not only does this moraine show no signs of left by a *retreating* glacier, but on the contrary I think it signs that the ice is *advancing*. For the snout of the ret is not only pressed hard against the moraine but the

* This Journal, III, v, 325.

outer slope of the moraine, when I saw it, in 1872, was just at the *limit of stability*—the least disturbance caused the fragments to roll down. It would seem therefore that the moraine is being pushed slowly forward. Whether the same is true still I know not.*

King, in his recent volume on Systematic Geology, already referred to, has drawn attention to still other evidence of snow advance in the high Sierra. According to him, above the timber belt, there is a comparatively bare region of one thousand feet vertical, on which for ages there has been too much winter snow to allow the growth of timber. In the timber region bordering the bare region there are many trees which have two hundred and fifty annual rings. These trees have therefore been growing securely for two hundred and fifty years. But since 1860 the snow has so advanced upon the timber region that these great trees are being destroyed by avalanches. It would seem therefore that not only has there been recent advance, but that it is the first advance for two hundred and fifty years.

The rise of the lakes in the desert region is therefore undoubtedly the result of a climatic cycle. But whether the cycle be a long or a short one; whether it be a geological cycle of increasing snow-fall—a turn of the cycle of dryness which, commencing after the Champlain epoch, culminated in the present arid condition of the desert region—or whether it be only a climatic fluctuation of short duration, and of which therefore geology takes no account, such for instance as may be supposed to be connected with the sun-spot cycle, it is impossible with certainty to determine without observations extending through a much longer period of time. I have hitherto been disposed to think the latter more probable, but King's observations on destruction of trees by avalanches, would seem to point to the probability of a long cycle.

* King, in his recent volume on Systematic Geology of the 40th parallel, p. 477, says that all Mr. Muir's living glaciers of the Sierra are only moving snow-fields well known to the California surveyors. He then quotes Agassiz defining the distinction between such moving névés or snow-fields and true glaciers. This distinction according to Agassiz consists in the ability to bear rock fragments on its bosom and thus to form a moraine. Now, it is but justice to Mr. Muir to say that the ice in the Lyell-Cirque does bear large rock fragments on its surface and accumulates them at its lower limit as a perfect terminal moraine. Recognizing, however, the fact that this ice mass does not emerge from its native cirque, I have, in my paper on "Ancient Glaciers of the Sierra" (this Journal v, 325), called it a *Glacieret.*

Berkeley, California, March 1, 1879.

V.—*On the Mineral Locality in Fairfield County, Connec-t;* by GEORGE J. BRUSH and EDWARD S. DANA. Third er.

the present paper we purpose giving an account of the s of our exploration of the Branchville locality during the year, so far as they relate to the manganesian phosphates. r preceding papers,* we have confined ourselves almost sively to the original body of phosphates exploited by Mr. r; we having mentioned in addition only the occurrence single small deposit of lithiophilite. When we first d the locality, our hope was to rediscover the body of als from which the specimens preserved by Mr. Fillow een obtained. Our success in this was quite indifferent; l, indeed, find the spot aimed at, and took from it a small ity of the minerals in which we were interested, but it on clear that this deposit was exhausted, and we must arther for other and independent ones. Having but little de us in our explorations, we extended them quite widely seemingly most probable directions and expended, in nd money, more than our final success would, perhaps, warranted. We discovered, however, many interesting in regard to the minerals occurring in the vein as a , which we intend to describe in another paper.

hiophilite.—As regards the phosphates, the mineral lithio-e has been proved to exist in considerable quantities. It usually not in large deposits, but in single, isolated s, from the size of a cherry to others several inches across. nethod of occurrence is quite uniform. The masses are lar in shape, sometimes rounded, sometimes angular, and enetrating the associated minerals in the most intimate er. These associated minerals are more particularly feld-usually albite, and spodumene. The latter mineral is very ally altered, and the various products of its alteration, ich cymatolite is the most common, we shall describe in er place. The lithiophilite, however, though often coated externally, is otherwise quite free from alteration; the exception to this was in the case of that first discovered, was situated near the surface of the ledge and was much zed. It will be remembered that, in what we have allu-o as the original deposits of phosphates, the lithiophilite red very sparingly and only as an occasional nucleus of s of the abundant black mineral, the product of its alter- This is described in our preceding paper, and analyses se oxidation products are there given.

* This Journal, July and August, 1878, May, 1879.

The lithiophilite of which we are now speaking has, in almost all cases, the salmon color of that first described. In one specimen the amount of iron was determined by Mr. Penfield and found to be but 3·56 per cent. The lithiophilite sometimes contains imbedded rhodochrosite. Other constantly associated minerals are: apatite, garnet, uraninite in brilliant black octahedrons, uranium phosphates, and a silicate containing uranium, near cyrtolite, all of which will be described later.

The lithiophilite was the only mineral of the manganesian phosphate group found in these small isolated deposits. A larger mass finally reached, however, gave us another variety of this mineral, and also several of the other species. This mass was of so peculiar a nature as to deserve a somewhat minute description. It afforded first, for the most part, only lithiophilite, but of a different color from that before obtained, and of slightly different composition as shown by the analysis given on p. 47. Closely associated with the lithiophilite was a considerable amount of a granular, often also cellular, manganesian carbonate, rhodochrosite. This was quite impure, often containing interpenetrated crystals of white apatite, and also quartz. With the lithiophilite and rhodochrosite, are small quantities of eosphorite and triploidite and traces of dickinsonite; we were interested in finding hand specimens, showing all these phosphates together, entirely free from alteration, and in such a juxtaposition as to seem to prove a contemporaneous origin. Crystallized out in cavities in the rhodochrosite and again in thin seams or strings through it was a reddish-brown mineral which proved to be chabazite.

Immediately connected with the minerals described, was a large mass of a green chloritic mineral, of which we took out some hundred pounds; this we describe minutely on a subsequent page. Its especial interest lay in the intimate manner in which it was associated with the minerals just mentioned. This is particularly true of the eosphorite, which was scattered irregularly through it in nodules of great variety in shape and size. These nodules have often a banded coating of a firm whitish substance, which may have been derived from the alteration of the original mineral, and which entirely conceals the eosphorite within.

Having given this general description of the method of occurrence of these minerals, we will now proceed to describe some of them more minutely.

LITHIOPHILITE.

We have already stated, that almost all of the lithiophilite discovered was similar in its salmon, and salmon-pink color, and, as far as tested, in composition, to that described in our

ıt paper; in other words, it contains from three to four per ıt of iron protoxide. The lithiophilite, associated with the ›en chloritic mineral, has a light clove-brown color. It has ›rilliant luster and is clear and transparent. The specific ıvity is 3·482. An analysis* by Mr. S. L. Penfield, afforded › following results:—

	I.	II.	Mean.	Atomic relation.		
P_2O_5	45·22	45·22	45·22	P	----	·636
FeO	13·10	12·92	13·01	Fe	·180	= ·631
MnO	31·93	32·12	32·02	Mn	·451	
Li_2O	9·26	----	9·26	Li	·618	= ·628
Na_2O	0·28	0·30	0·29	Na	·010	
H_2O	0·17	----	0·17			
Gangue	0·31	0·28	0·29			
			100·26			

Γhe ratio, $P:\overset{II}{R}:\overset{I}{R}$=·636 : ·631 : ·628, corresponds very closely ›h the formula previously accepted,

$$\overset{I}{R}\overset{II}{R}PO_4 \text{ or } \overset{I}{R}_3PO_4 + \overset{II}{R}_3P_2O_8.$$

will be observed that the amount of iron in this variety of › mineral is considerably greater than in that first described l alluded to above. This result is not surprising, and indeed s anticipated from the color of the specimen. Mr. Penfield, the article referred to, has brought together the analyses of ›eral varieties of triphylite and the two of lithiophilite, and ıs shows the gradations between the two species. The one ›reme is the Bodenmais triphylite with 36·21 p. c. FeO, and 6 p. c. MnO, and the other the original lithiophilite, with 2 p. c. FeO, and 40·86 p. c. MnO. The relation between ›se two minerals, is closely analogous to that existing between › iron and manganese carbonates, siderite ($FeCO_3$), and rho- ›hrosite ($MnCO_3$). There is the same similarity in physical ›racters, the most pronounced difference being here as there the color, so that the necessity of giving the two minerals of › triphylite group distinct names cannot be questioned.

Eosphorite.

The eosphorite we have spoken of as forming nodules im- ›dded in the massive green chloritic mineral. It occurs only ›ssive, but shows the characteristic cleavage distinctly and is ›ar and lustrous. The color is a beautiful pink, sometimes ›ite deep. The specific gravity is 3·11. An analysis by Mr. ›race L. Wells gave the following results:—

* This analysis has already been published by Mr. Penfield in an article on the ›nposition of triphylite; this Journal, March, 1879.

			Ratio.	
P_2O_5	31·39	P_2O_5	·221	1·06
AlO_3	21·34	AlO_3	·208	1·
FeO	6·62	FeO	·323	
MnO	22·92	MnO	·092	2·12
CaO	1·48	CaO	·026	
H_2O	15·28	H_2O	·849	4·04
Insol.	1·46			
	100·49			

The ratio of $P_2O_5 : AlO_3 : RO : H_2O$ is very nearly 1 : 1 : 2 : 4 or that given in our former paper, and upon which the formula was based, viz :—

$$R_2AlP_2O_{10}, 4H_2O \text{ or } AlP_2O_8 + 2H_2(Mn,Fe)O_2 + 2aq.$$

The Green Mineral.

The larger part of this deposit consisted, as already stated, of a soft green compact mineral, varying in tint from light grayish and yellowish-green to dark blackish-green. Luster dull to greasy. Hardness = 2·5. Specific gravity of the purest portions = 2·85 to 2·89. This material was exceedingly impure, containing, imbedded in it, the feldspar and mica of the vein, also quartz, apatite, chabazite, as well as the phosphates, most conspicuously among these, the eosphorite. It was possible, however, to obtain small hand specimens showing the green mineral in a state of comparative purity. A series of ten thin sections was prepared from specimens which appeared most homogeneous, and these were carefully examined under the microscope. It was found from them, that the substance was, for the most part, fine granular and crypto-crystalline, but that numerous quartz grains and apatite needles were scattered through it. The crypto-crystalline ground-mass could not be resolved under the microscope and had every appearance of homogeneity, but it would be unsafe, considering the nature of the substance, to assert this positively. In any case the presence of distinct, though microscopic impurities, makes it quite hopeless to think of obtaining a definite chemical composition.

A specimen as pure as we were able to obtain, has been analyzed by Mr. Horace L. Wells with the following result:—

	I.	II.	Mean.	Ratios.
SiO_2	20·71	20·73	20·72	·345
AlO_3	14·71	14·64	14·67	·158
FeO_3	2·67	2·67	2·67	·016
FeO	19·48	19·65	19·56	·272
MnO	2·21	2·23	2·22	·031
MgO	5·22	5·16	5·19	·130
Na_2O	0·51	....	·51	·008
K_2O	0·09	....	·09	·001
Li_2O	*tr.*	....	*tr.*	
CaO	12·40	12·27	12·34	·220
P_2O_5	8·81	8·87	8·84	·622
Insol.	3·84	3·94	3·89	
H_2O	8·83	8·84	8·84	·491
			99·54	

It is evident from the above, independent of the microscopic examination, that the substance analyzed is not a simple mineral. If we assume the 8·84 per cent of phosphoric acid to be combined with sufficient lime to form the mineral apatite, and deduct this amount and also the insoluble matter, we have a remainder of 75·19 per cent, which when calculated to the original amount gives the following composition:—

SiO_2	27·43	MgO	6·87
AlO_3	19·42	CaO	0·95
FeO_3	3·54	Na_2O	0·68
FeO	25·89	K_2O	0·12
MnO	2·94	H_2O	11·70
			99·54

It is scarcely admissible to attempt a formula for a substance which is so evidently a mixture, but we believe the results indicate that the green mineral is unquestionably a variety of chlorite. The analysis, excluding apatite and the insoluble residue, brings the composition very near that of delessite and prochlorite. Its physical characters, also, confirm its claim to be referred to the chlorite group.

The mineral gives water in the closed tube, and B. B. fuses to a black magnetic mass; with the fluxes it reacts for silica, iron and manganese. Soluble in hydrochloric acid with separation of silica, and an insoluble residue which was separated from the silica by solution of the latter in boiling carbonate of soda. The insoluble residue proved to be a silicate of alumina, possibly cymatolite which occurs at the locality in great abundance.

Chabazite.

This species occurs of a dark yellowish to reddish brown color, in irregular masses disseminated through quartz, and sometimes imbedded directly in the green chloritic mineral, and also in the massive manganesian carbonate occurring with the lithiophilite. A few small crystals, $\frac{1}{4}$ to $\frac{1}{2}$ inch over, were found in cavities. This singular mode of occurrence, in irregular spots and strings imbedded in other species, was so unlike the ordinary association of chabazite, that we could scarcely credit its being this species, although the pyrognostic characters, rhombohedral form ($R \wedge R = 96° 45'$), density, hardness and other physical characters plainly indicated its specific relations. The analysis given below, however, renders its identification with chabazite complete; this analysis was made by Mr. Penfield on the purest material which could be obtained. It was found impossible to separate it entirely from the quartz.

The chabazite has a vitreous to sub-resinous luster. The hardness is 4·5 and the specific gravity is 2·16.

An analysis of a carefully selected specimen by S. L. P field gave

Silica	49·22
Alumina	17·58
Iron sesquioxide	1·99
Manganese protoxide	0·56
Lime	6·73
Potash	2·83
Soda	1·44
Water	17·83
Quartz	2·78
	100·96

RHODOCHROSITE.

It will be seen from what has been said in this and in first paper, that rhodochrosite is a very common mineral ir association with the phosphates. In the first deposit it occu sometimes in specimens of large size with the characteri color and cleavage ($R \wedge R = 106° 49'$), and again in gran aggregates interpenetrated with quartz, and often takin greenish color from the dickinsonite. It also appears alt to a black, highly lustrous mineral, containing only the ox of iron and manganese.

In the deposits which form the special subject of this pa the rhodochrosite occurs first of a pink color implanted in lithiophilite and hardly to be distinguished from it except its cleavage; and again in large masses of a white or fai pink color, granular texture, and made very impure from admixture of quartz and apatite. This variety of the min occurs with the clove-brown lithiophilite and the green chlo mineral, and contains in cavities crystals of quartz, apatite chabazite. We add here an analysis by Mr. S. L. Penfi of the first discovered rhodochrosite; specific gravity = 3·7

	I.	II.	Mean.	Ratio.		
CO_2	37.78	37·80	37·80		·859	1
FeO	16·74	16·78	16 76	·233		
MnO	44·68	44·50	44·59	·628	·867	1
CaO	0·33	0·33	0·33	·006		
MgO	*tr.*	*tr.*	*tr.*			
Insoluble	0·35	0·29	0·32			
	99·88	99·70	99·80			

The variation in color of the mineral implies that the c position varies widely, which would doubtless be shown, cc analyses of different varieties be made. The interest conne with the subject is, however, small, although the large amc of iron present is worthy of note.

ART. VI.—*Note on the Progress of Experiments for comparing a Wave-length with a Meter*; by C. S. PEIRCE. Communicated by the Superintendent of the U. S. Coast and Geodetic Survey.

C. P. PATTERSON, Superintendent U. S. Coast and Geodetic Survey:—

DEAR SIR—The following is the present state of the spectrum meter business. The deviation of a spectral line (Van der Willigen's No. 16) has had three complete measures using a certain gitter of 340½ lines to the millimeter. The double deviation (the angle measured) was found to be

1877.	June 23,	89° 54′ 19″·5
	June 29 and July 2,	19·25
	Sep. 4 and Aug. 27,	19·65
	Mean,	89° 54′ 19″·5

An error of 0·4″ in this would occasion an error of one micron in the meter. These measures were previously communicated to you, but owing to an erroneous value of the coefficient of expansion of glass having been used (the value for iron having been inadvertently substituted) they did not seem to agree as well as they do. There were two other complete measures, but in regard to one of them there is a doubt about the thermometer used, and in regard to the other there is a doubt about the part of the line set on. This line seems on the whole to be a bad one for the purpose. Another line near it was therefore selected and another much finer gitter. The deviations obtained were on the different days:

1879.	May 8,	90° 03′ 51″·7	May 15,	90° 03′ 50·35
	May 9,	51·75	May 21,	51·75
	May 10,	52·0	May 22,	51·2
		Mean, 90° 03′ 51″·45		

Notwithstanding the bad result of May 15, which is unaccountable, these measures are evidently good enough. One of these gitters has been compared with all the centimeters of a decimeter scale of centimeters. The other is still to be compared with all the even two centimeters of the same scale.

Mr. Chapman is now comparing this decimeter scale with all the decimeters of a meter scale of decimeters. As soon as that is done *a meter* will have been compared with a wave-length. But shortly after, this will be improved by comparing the other gitter and also a third upon which I propose to measure a deviation. It will remain, first, to find the coefficient of expansion of the glass meter. The apparatus is all ready for this and it will not take a fortnight. Second, the glass meter will have to be compared with a brass meter. This will be an operation of some difficulty but I think we shall complete it before long.

Yours respectfully, C. S. PEIRCE, *Assistant.*

ART. VII.—*Notice of recent Additions to the Marine Fauna of the Eastern Coast of North America, No. 6*; by A. E. VERRILL. *Brief Contributions to Zoology from the Museum of Yale College.* No. XLIII.

POLYZOA.

Bugula decorata, sp. nov.

Zoarium rather large with thick, much branched stems, producing densely branched, somewhat plumose tufts, two inches or more high. Branches unequally dichotomous, often somewhat spirally arranged. Zoœcia in two alternating rows, large, broad, prolonged proximally. Frontal area, large, elongated, sunken and wrinkled in the dry state. The distal angles are prolonged into a single stout, often short spine on each side, frequently absent on the inner angle. Avicularia on the middle of the front side of the zoœcia, toward the base; they have a short, broad, swollen head, with a short strongly curved beak; the pedicels are short and thick, rapidly enlarged from the base upward. Oœcia large, globose, brilliantly iridescent, elegantly sculptured, with a series of raised curved lines passing up over each side and converging to the middle of front side, while their concave interspaces are covered with microscopic transverse lines. Dredged at Eastport, Me., by the writer, and also in the Gulf of Maine, 110 fathoms, near George's Bank, by Dr. A. S. Packard and Mr. C. Cooke, in 1872 (U. S. Fish Com.). The other species of *Bugula* found on the New England coast are as follows:

Bugula cucullata, sp. nov. Off Maine. Remarkable for the small, hood-like, upturned oœcia, widely open in front. Zoœcia in two rows; usually two spines on each angle; avicularia lateral.

Bugula turrita (Desor) Verrill. Florida to Casco Bay.

Bugula avicularia (L.) Oken. Long I. Sound to Spitzbergen.

Bugula fastigiata (L.) Alder (= *B. plumosa* Busk). Mass. Bay to Labrador; Europe. Perhaps a variety of the last.

Bugula flustroides (Lamx.) (= *B. flabellata* Gray). Long I. Sd. to Maine; Europe.

Bugula Murrayana Busk. Long I. Sd. to Europe.

B. Murrayana, var. *fruticosa* (Packard).

Bugula flexilis Verrill and *Bugula umbella* Smitt, belong to the genus *Kinetoskias* Dub. and Kor. Both occur in deep water off Maine and Nova Scotia.

Notwithstanding the very numerous restrictions which the ancient genus *Cellularia* has undergone, it is still made to include heterogeneous species by several recent writers, while others restrict it to groups not originally included by Pallas. In the excellent memoirs of Smitt on the Arctic Bryozoa, five species still remain in the genus *Cellularia*. These belong to three well-marked groups, and their synonymy is very

complicated. Having had occasion to revise this family, I offer the following summary of the New England species.

I. *Cellularia* Pallas, 1766, (restricted). Zoœcia unilateral, in two alternating rows, mostly protected by lateral spines, either simple or dilated. Vibracula and lateral and median avicularia present. Type *C. scruposa.**

a. Subgenus *Cellularia.* (=*Scrupocellaria*, *pars*, Gray, Busk). Lateral spines all simple.

b. Sub-genus *Cellarina* Van Ben. (incl. *Tricellaria* Flem., 1828.) One of the lateral spines usually more or less dilated, and often expanded in a shield-like form in front of the zoœcia. Two New England species: *C. scabra* Van Ben.; and *C. ternata* (Sol.) with varieties *gracilis* and *duplex* (Smitt).

The name *Tricellaria* (given to *ternata*), might have been adopted for this subgenus, but is very inapplicable to the group, and even to the type-species, as now known.

II. *Scruparia* Oken (restricted), (= *Scrupocellaria*, *pars*, Gray; *Canda* Busk, *non* Lamx.). Lateral avicularia and vibracula absent. A lateral spine develops into a protective (often frondose) shield. Type *S. reptans* (Linné), not yet found on the American coast.

III. *Bugulopsis* Verrill (= *Cellularia*, *pars*, Busk, *non* Pallas). Characterized by the simple, unarmed zoœcia, arranged in alternating rows, and destitute of avicularia, vibracula and shields. Type *B. Peachii* (Busk). Gulf of Maine and Bay of Fundy. European seas, north to Spitzbergen.

As no species of the last group was originally included in *Cellularia*, it is inadmissible to restrict that name to it. Therefore either *reptans* or *scruposa* should be taken as the type of *Cellularia*, both having been originally included by Pallas, as well as by most subsequent authors. *Scruparia*† Oken (1815) originally included not only the group that had previously been named *Eucratea* by Lamouroux (1812), but also *S. reptans.* Therefore there seems to be no good reason why it should not be restricted, as above, rather than be displaced by the much later and more objectionable name, *Scrupocellaria. Menipea*, used by Busk and others for *Cellarina*, is inadmissible, in that sense, for the original group thus named by Lamouroux is a valid and very distinct genus. *Canda* (Lamx., 1816), adopted by some for *Cellularia reptans*, cannot properly be so used, for the original type is a distinct genus.

Porellina stellata, sp. nov.

A large, handsome species, forming radiating patches on shells, etc. Zoœcia arranged in quincunx, large, broad, mod-

* This species has been recorded from the Gulf of St. Lawrence by Packard and others, but I have myself seen no American examples.

† This name has recently been given to a new genus, in a new sense, by Hincks, in accordance with a practice that is nearly always unsafe, as well as confusing.

erately convex, white, shining, mostly imperforate and smooth, the marginal ones more or less perforate in front. Apertures nearly semi-circular, the proximal edge straight or nearly so, often with two spines on the distal border, median pore, a short distance from the aperture, large, nearly circular, provided with numerous, slender, convergent spinules, which nearly reach the center, giving the pore a stellate appearance. Avicularia near the lateral margin, about opposite the median pore, varying in size and form: in the same colony some are short triangular, others long triangular, while others with a long and acute, erect tip show the transition toward vibracula. Length of zooecia, ·60 to ·70^{mm}; breadth, ·50 to ·60^{mm}; breadth of apertures, ·12 to ·15^{mm}; of median pore, ·05 to ·06^{mm}. The zooecia are about twice as large as those of *P. ciliata.*

Casco Bay, Maine. (U. S. Fish Comm., 1873).

In the nearly circular form of the median pore this species approaches the genus *Porina*, as restricted by Smitt, (Florida Bryozoa), but in all other respects, except size, it agrees so closely with *P. ciliata*, made the type of *Porellina* by Smitt, as to forbid a generic separation, although the latter has a crescent-shaped pore. It would belong to *Microporella* Hincks, if that name be adopted.

Art. VIII.—*Positions of the Planets Philomela and Adcona;* by C. H. F. Peters.

I communicate a few observations on a planet discovered by me on the 14th of May. I have given to it the name *Philomela*, as the name *Prokne* is applied to the one discovered on March 21. The planet lately found (May 21) by Mr. Palisa seems to be *Adcona* (145), which for several years had been searched for in vain, its elements having remained very uncertain, since my observations at its first appearance, the only ones made upon it, did not extend over more than about a month (from June 3 until July 7, 1875). I append the two positions I succeeded in getting before the last moon.

Observations on *Philomela* (196).

1879.	Ham. Coll. m. t.	App. α.	App. δ.	log (p. ·Δ)		No. of comp.
May 14.	11^h 56^m 31^s	12^h 16^m 39^s·02	+6°52′46″·9	0·682	0·736	12
16.	10 37 6	12 16 21·21	6 48 5·7	0·509	0·724	10
18.	12 25 36	12 16 6·75	6 42 30·7	0·747	0·746	10
20.	9 51 4	12 15 58·20	6 36 57·0	0·391	0·723	12
25.	10 22 18	12 15 57·02	6 19 57·8	0·572	0·731	10
June 5.	10 6 55	12 17 37·14	+5 32 34·6	0·634	0·742	9

Observations on *Adcona* (145) (?).

1879.	Ham. Coll. m. t.	App. α.	App. δ.	log (p. ·Δ)		No. of comp.
May 28.	14^h 27^m 1^s	15^h 55^m 11^s·71	−15°30′22″·8	0·677	0·851	8; 4
29.	12 40 30	15 54 18·81	−15 30 54·6	0·343	0·875	12

Litchfield Observatory of Hamilton College, Clinton, N. Y., June 6, 1879.

:T. IX.—*A Method of Preventing the too rapid Combustion of the Carbons in the Electric Lamp;* by H. W. WILEY.

:N using the electric light for projections, two chief points to be considered, viz: 1st, brilliancy of illumination, and steadiness of the light. When the source of electricity is ficient, the first of these ends is easily obtained. The sec-l, however, is not so easy of accomplishment. The chief iculty in the way of securing steadiness is found in the car-is themselves. Some carbons, and I find these to be the st common, burn away so rapidly that, where no mechanism present to produce alternating currents, the electric arc is istantly passing out of the focus. Often, too, I have found t when the current is quite strong with the softer carbons, arc would extend itself momentarily between points as far a centimeter from the end of the carbons. At other times vould revolve about the electrodes something like a spiral ne in a pyrotechnic display. This leaping and dancing of arc is, of course, fatal to its employment for projection.

[n order, if possible, to remedy these defects in a lantern ich I have in almost daily use, I made the following experi-nts. I first took the specific gravity of three specimens of bon, obtained from different dealers, one in France and two this country. The specific gravity of the French carbon, s 1·85; of No. 1, American, 1·53; of No. 2, American, 5. The French carbon is hard, of a grayish black color. e American carbon is soft, easily broken up, and has no n of a metallic luster. The light from the French carbon is ite steady and displays very little of that tendency to flicker, troublesome in the American varieties.

A positive French carbon, which had been used for several urs, until consumed nearly to the lamp, burned away at the int, but otherwise retained its original shape. This carbon is used without any previous preparation.

A soft carbon, however, of the same size as the preceding, came red hot to a distance of four to six centimeters from e end, and rapidly wasted away; after being in use for half hour, it was reduced to a slender, tapering form.

I first tried the plan so well known in France, but so seldom ied here, of coating the carbons with a film of copper. The ecipitation of the copper should take place slowly, and with current so regulated in quantity and intensity as to produce spongy deposits. When the soft carbons were thus pre-red they worked beautifully for a short time. The light was rilliant and steady, while any green tint imparted to it by the olatilized copper produced no effect whatever prejudicial to

the purpose in view. But as the carbons, little by little, became heated, the copper film oxidized, and after half an hour the carbon was again reduced to the slender form above described.

I next tried the expedient of setting a copper wire, ·4^{mm} in diameter, into the center of the carbons. With a thin saw I cut a longitudinal groove to the center of the carbon, and after inserting the wire fixed it in place by filling the groove with plaster. The upper end of the wire was left projecting so that it could be brought into actual contact with the clamp. I hoped from this contrivance to hold the origin of the arc steadily at the end of the carbon and, at the same time by increasing the conducting power, to prevent the heating and consequent rapid consumption of the electrode. In placing the carbons in the lamp the grooved sides were turned from the lens. This device proved very successful in securing a steady light, but the carbons were heated to their points of insertion in the holders and wasted rapidly away. The point, it is true, remained blunt, but the stem of the carbon burned away so rapidly that the experiment must be regarded as unsuccessful.

It was evident from my first experiments with copper-plated carbons, that, if any way could be devised of protecting the copper from oxidation, the copper would prevent the carbon from heating by increasing its conductivity, and diminishing the resistance. I accordingly covered the carbons, after copper-plating with a film of plaster of Paris, about 1^{mm} in thickness. After this had set, the edge of the carbon, which was to be turned towards the condenser, was carefully denuded of its plaster-covering, which was also cut away until quite thin on the adjacent surfaces. These precautions were taken so that the plaster might not interfere with the radiation of light in the direction of the condenser. Before use the plaster must be thoroughly and slowly dried. The copper surface at the end of the carbon being uncovered it is fastened in the holder in the usual way. The carbons prepared in the way described left nothing to be desired. The light was steady and the carbons burned slowly away. The film of plaster melted gradually as the point was consumed and thus never interfered with the illumination. The points of both positive and negative carbons remained blunt, and there was no wasting away of the stem. A carbon prepared in this way will last at least ten times as long as one used in the ordinary way. But the chief advantage is found in the comparative steadiness of the light thus secured.

Carbons of the above description work best when well plated. The following numbers give what I regard as a minimum amount of copper to secure satisfactory results. In all

› experiments I have tried, the carbon has been of the soft nerican variety, with an average specific gravity of 1·55.

Length of carbon, ...	17·5 cm.
Each side, ...	1 "
Number $\overline{\text{cm.}}^2$ of surface including ends, ...	72 $\overline{\text{cm.}}^2$
Weight before coppering, ...	21·1615 g.
Weight after coppering, ...	24·0410 "
Weight of copper, ...	2·8795 "
Weight copper to each $\overline{\text{cm.}}^2$, ...	·0397

In order to dispense with the use of a reflector, I arrange the :bons + above as described in the Journal of Franklin stitute for May and June, 1878.

The peculiar cup-shaped appearance of the positive carbon lps to concentrate the light on the condenser. It is underod that any lamp, in which the carbons are arranged end to l, can be used with electrodes prepared as above. Such a np can be easily substituted in a lantern made for use with y-hydro-lime light. I use constantly such a lamp with one of lgerton's physical lanterns originally made for the lime light. ım inclined to think a kaolin paste would be better than ıster for coating the carbons. The electric force used in all › experiments has been furnished by the Gramme machine, scribed in the Journal of the Franklin Institute already cited.

The use of projections for illustration in lectures on Chemry and Physics has become so general that I hope the sugstions in this paper may prove of some benefit.

'urdue University, Lafayette, Indiana, April 18, 1879.

RT. X.—*Bernardinite: a new Mineral Resin from San Bernardino County, Cal.;* by J. M. STILLMAN, Ph.B.

THROUGH the kindness of Mr. B. B. Redding, of San Fransco, I have been put in possession of some specimens of a :w and interesting mineral said to occur in considerable quan:y in San Bernardino County, California, and exposed by ccavations for a tunnel. The pieces in my possession were omogeneous masses of from one to five or six cubic inches mensions, and appeared to have been broken from still larger asses. It presents a nearly white mass, friable, light and porıs, containing much enclosed air, so that it floats on water ke cork. On fracture it presents a slightly fibrous structure. 'nder the microscope it exhibits a two-fold structure—a quanty of very fine irregular fibers permeating a mass of a brittle, norphous, structureless substance. No definite structure ›uld be perceived indicating previous woody or vegetable

tissue. The specific gravity of the mineral freed from air was determined as 1·166 at 18° C. The mineral does not melt perfectly at 140° C., but softens *slightly* at temperatures below 100° C.

It is insoluble in water;—entirely soluble in hot absolute alcohol, about 86·6 per cent dissolving on boiling for some time. The soluble portion is quite soluble, remaining in solution in about 2½ parts of hot alcohol. In cold absolute alcohol it is not so soluble, about one-third of that portion soluble in hot alcohol, not re-dissolving in cold. The alcoholic solutions are of a slightly yellow color, marked bitter taste, and acid reaction. Ether dissolves about one-third of the native mineral at ordinary temperatures. Carbon disulphide dissolves it but slightly. The residues from the solutions were in every case white and amorphous.

The extract with hot alcohol melts at temperatures between 115° and 125° C., but has no constant melting point, and softens somewhat at lower temperatures. On cooling after fusion it forms a brittle, translucent mass. Heated on platinum foil the mineral burns with smoky flame, with fixed carbon residue, but with only a trace of ash. An ash determination gave 00·12 per cent of a white, infusible ash, evidently silica. With concentrated sulphuric acid it gives a red-brown color, which on warming becomes black; on dilution with water black flakes are precipitated. The mineral, dried for several days over sulphuric acid, lost on heating to temperatures below its melting point 3·87 per cent in weight, probably, though not certainly, water. It contains no nitrogen. Elementary analysis of the mineral dried over sulphuric acid gave—

Carbon	=	64·53	per cent.
Hydrogen	=	9·20	"
Hence Oxygen	=	26·27	"
		100·00	

Admitting the loss in weight above quoted, of 3·87 per cent, as being due to loss of water, we should have as a complete analysis—

Water	3·87	per cent.
Carbon	64·46	"
Hydrogen (not in water)	8·75	"
Oxygen (not in water)	22·80	"
Ash	0·12	"
	100·00	

In caustic potash the mineral dissolves very readily and almost completely (93·5 per cent). The solution when concentrated is of a light, clear, brownish-yellow, and may be diluted

any extent with distilled water without precipitation, but ;h dilute chlorhydric acid gives a flocculent precipitate ich settles to the bottom on standing. The alkaline solun is gelatinous in the cold when concentrated, but dissolves dilution, and gives a froth like soap-suds on agitation. The :tion insoluble in caustic potash (6·5 per cent) is left as a ie-like mass of a brownish color.

A quantity of the mineral was dissolved in caustic potash, ecipitated with chlorhydric acid; the resin thus obtained was ojected after drying to elementary analysis. It gave—

$$\left.\begin{array}{lcl} \text{Carbon} & = & 69{\cdot}71 \text{ per cent.} \\ \text{Hydrogen} & = & 9{\cdot}59 \quad \text{"} \\ \text{Oxygen} & = & 20{\cdot}70 \quad \text{"} \end{array}\right\} 100{\cdot}00$$

e melting point of this purified resin was determined at 7°–129° for perfect fusion, though softening at lower temratures.

The acid character of the alcoholic solution, the oxygen conits, the behavior toward solvents, and especially toward caus- potash, as well as the temperature at which it melts, all licate the resinous character of the new mineral. To conm this it was treated in alcoholic solution with alcoholic solun of lead acetate, and a flocculent, white precipitate of the id resinate was obtained. It is noticeable that the oxygen ntents of this resin, as evidenced by both analyses, is much eater than is usually found in resins either of mineral origin freshly obtained from plants.

The filtrate, obtained by dissolving in caustic potash and ecipitating with chlorhydric acid, was evaporated to dryness id exhausted with alcohol, and a small quantity of a yellowh waxy substance obtained of an intense bitter taste, evi- :ntly the substance to which the bitter taste of the mineral as ell as of its alcoholic extract is due, as the purified resin pos- ssed no bitter taste.

This new resin appears to possess entirely different propers and composition from any organic mineral heretofore escribed. The South American mineral Guyaquillite seems) resemble it in some properties, but differs very materilly in other essential properties as well as in composition. Berengelite, also from South America, possesses a somewhat imilar elementary composition ($C_{20}H_{30}O_4$), but differs in all ther essential properties. At the suggestion of Mr. Redding, o whom I am indebted for the specimens which form the subect of the foregoing examination, I propose the name of *Berardinite* for the new mineral, from the name of the locality.

I hope soon to be able to subject the mineral to a more horough investigation, with the object of ascertaining the true hemical nature of its constituents.

University of California, February, 1879.

ART. XI.—*Notice of a new Jurassic Mammal;* by Professor O. C. MARSH.

DURING a recent visit to the Rocky Mountains the writer spent some time in examining the deposits known as the Atlantosaurus beds, and was rewarded by the discovery of several interesting fossils, among them the lower jaw of a small mammal. This specimen indicates a dimunitive marsupial, quite distinct from the one previously described by the writer from the same horizon (*Dryolestes priscus*),* which has hitherto been the only mammal known from the Jurassic of this country.

The present specimen, which is from the left side, has the larger part of the ramus preserved, with a number of perfect teeth in position. Most of the symphysial portion is lost, and the posterior part is missing, or only faintly indicated. The jaw was remarkably long and slender. The horizontal portion is of nearly equal depth throughout, and the lower margin nearly straight. The form of the coronoid process, condyle, and angle of the jaw cannot be determined from this specimen.

The remarkable feature in this jaw is the series of premolar and molar teeth. These were very numerous, apparently as many as twelve in all, and possibly more. The premolars had their crowns more or less compressed, and recurved, and some of them were supported by two fangs. These had a small posterior tubercle at the base of the crown, but none in front. The molar teeth were all single-fanged, with elevated conical crowns. Those preserved have a distinct cingulum. The molars increase in size from the first to the fifth. All the teeth preserved have the crowns raised considerably above the upper margin of the jaw, and thus appear to be loosely inserted. A large pointed tooth lying near the jaw appears to be a canine.

The principal dimensions of this specimen are as follows:

Length of portion of jaw preserved	11·5 mm
Extent of five molar teeth	4·
Extent of entire molar series	5·
Height of fifth true molar above jaw	2·
Depth of jaw below fifth molar	1·75
Depth of jaw below last premolar	1·5
Depth of jaw below first premolar	1·4

In comparing this interesting fossil with the forms already known, it is at once evident that it differs widely from any living type. Its nearest affinities are clearly with the genus *Stylodon* of Owen, from the Purbeck beds of England,† and in many respects the correspondence is close.

* This Journal, vol. xv, p. 459, June, 1878.

† Geological Magazine, vol. iii, p. 199, 1866, and Palæontographical Society, vol. xxiv, p. 45, 1871.

This specimen clearly indicates a new genus, which may be called *Stylacodon*, and the species represented, *Stylacodon gracilis*. With the genus *Stylodon*, this form evidently constitutes a distinct family, which may appropriately be termed the *Stylodontidæ*. The present specimen indicates an animal somewhat smaller than a weasel, and probably insectivorous in habit.

Yale College, New Haven, June 18th, 1879.

Art. XII.—*On the Hudson River Age of the Taconic Schists;* by James D. Dana. Supplement.

In the preceding part of this paper, the courses of the bedding of the rocks are indicated only in a general way. In this supplement, I give the results observed in Dutchess County as to strike and dip, together with some other omitted details.

1. *Wappinger-Valley Belt.*—This limestone belt leaves the Wappinger Valley about a mile northeast of Salt Point (or five miles from Pleasant Valley), the Creek—not the limestone belt—here changing its course by taking an eastward turn for a mile. From this point it has a small brook, flowing from Upton's Lake, as its southern limit, instead of the Wappinger stream; at the same time, its width—which was nearly a mile at Manchester, 3000 feet at Pleasant Valley, and, according to Professor Dwight, 2200 at Salt Point, continues to diminish; and, about half a mile west of Willow Brook station, the southern part of the belt ends. It appears again in the Wappinger Valley, about two and a half miles to the eastward, north of Bangall. The following are the results obtained with reference to the strike (or direction of bedding, allowance being made for variation, and the dip of the limestone and the associated schist) commencing at the south. As has been stated, the schist in Dutchess County, going from west to east, varies very gradually from dull to shining argillyte and thence to hydromica schist, on the north; and, on the south, from the same to mica schist and micaceous gneiss.

At East Mills, 4½m. S.E. of Poughkeepsie, the schist east of Wappinger Creek, strikes N. 39°–40° E., dip 75° E. (that is, eastward, but at right angles to the strike). At Manchester, limestone N. 17°–25° E., dip 50°–60° E.; schist, E. of river, N. 20°–21° E., 60° E.; the width of the limestone east of creek, about 2000 feet, and west of it, 3000 feet. At Rochdale (Titus's woolen factory) fossiliferous limestone, N. 37° E., dip 60° E. (650 feet west of the eastern junction with the slate). At Pleasant Valley, where the limestone is almost wholly north of the creek, N. 32° E., dip 85°–90° E., at a locality not far from its northwestern limit; and at the quarry near the river, about 200 yards from the southeastern limit, N. 24° E., dip 60° E. At Salt Point, according to Professor Dwight, N. 26° E., dip 70°–85° W. Southwest of Willow Brook ¾ m., limestone N. 19° E., dip 50°–60° E.; a mile east

of Willow Brook, S. side of Wappinger Creek, schist N. 16° E., dip 60° E., and ½ m. N.E. of last, N. 14° E., dip 50°–60° E. At Stanfordville, schist S. of river, N. 28° E. (average), dip 60° E. (varying, much contorted); 200 yards above station N. of river, a *layer of grayish quartzyte in the schist*, 25 to 30 feet thick, strike of slate and quartzyte, N. 16° E., dip 60° E.; just north of river ½ m. W. of Bangall, schist N. 28° E., dip 75° E., and here a fault, the limestone adjoining being nearly horizontal. Between Pine Plains and Stissingville, much of the limestone nearly horizontal, with small eastward dip, varying to westerly. At Stissingville near railroad, limestone N. 12° to 17° E., dip 40°–45° W., and schist near by, N. 12° E., same dip; one mile E. of station, dip 30° E. At Ancram Lead Mine, limestone N. 19° E., dip 60°–70° E.; 3 m. north, limestone N. 19° E., 50°–60° E.; in Copake, 1 m. south of village, limestone N. 13°–16° E., dip 40° E.; near Copake Iron Furnace, schist of Taconic Mtn., N. 10°–15° E., dip 50° E. (average); 3 m. S. of Furnace, adjoining Taconic Mtn., limestone and schist N. 15° E., dip 50° E.

2. *Shekomeko Limestone area.*—The area occupies the valley between Husted station and Pulver's Corners. Thence it extends south-southeast, widening, and ends half a mile south of where the road from Bangall enters the valley. In a cut just northeast of Husted station, limestone N. 25° E., dip 35° E.; schist in next cut, 400 yards to the northeast, N. 25° E., dip 40°–50° E.; 300 yards farther northeast, N. 14° E., dip 50°–60° E.; 1 m. eastward, schist of Winchell's Mtn., N. 16° E., dip 48° E.; on the mountain, 250 yards W. of Winchell's station, schist N. 16° E., dip 20°–60° E., average 40°. Nearly three miles S. of Husted's, just below Shekomeko station, limestone, N. 32°–37° E., dip 50°–60° E.; toward western limit of limestone area, an intercalated stratum of schist, N. 35° E., dip 50°–60° E.; west of this schist, limestone with same position; ¼ m. S. of Shekomeko station, limestone N. 27°–37° E., dip 15°–50° E. W. of south end of the limestone area, slate, near road to Bangall, N. 20°–32° E., dip in undulations, 10°–50° W., but ½ m. to the west, it is 40°–50° E.

3. *Fishkill-and-Millerton belt*, commencing at the southwest.—At Matteawan depot, argillaceous schist on railroad, N. 40° E., dip 70° to 80° E.—a fine-grained, fissile rock, of little luster, fusing B. B. to a slightly magnetic globule, and hence probably an argillitic mica or hydromica schist; ½ m. S.E. of Matteawan, at junction of schist and limestone, N. 52° E., dip 70° E.; ½ m. N.E. of Matteawan, limestone N. 42° E., 70°–80° E.; half way to Glenham (or 1 m. from Matteawan), limestone N. 47° E., vertical; ¾ m. southwest from Glenham, N. 52° E., 60° W.; again ½ m. from G., N. 47° E., 45°–50° W.; in Glenham, on river, limestone and "bastard granite" making parallel walls on opposite sides of the stream, strike of each, N. 37° E., dip 70°–80° E., and south of river, near mill-dam, limestone N. 52°–57° E., dip 35° W., north of river 300 yards, schist N. 22° E., dip 60°–70° E., with "bastard granite" near by to north much jointed and uncer-

ı in strike, becoming near the slate a gray quartzytic variety; th of Glenham station, on river, limestone N. 52°–62° E., dip W. East of Fishkill station ½ m., limestone N. 52° E. (aver-), dip 55°–60° W. Between this and Brinkerhoff station, ⅛ m. n B., wide variations in strike and dip of limestone, N. 28° W., l even 55° W. to N. 12° E., dip 20°–35° E.; E. of B., ½ m., estone N. 16° E., dip 50° E.; 1 m., same N. 2°–14° E., 50°–60° 1½ m. W. of Hopewell, limestone N. 40° E., dip 60° E. One e southeast of Poughquag, 200 yards west of quartzyte, lime-ne N. 32° E., dip 40° W.; ½ m. S. of P., limestone N. 32° E., 40° E.; ½ m. W. of P., N. 37° E., 40°–50° E.; at Beekman's m. W. of P., limestone N. 22° E., dip 40°–50° E.; 3½ m. W. P., north of Silver Lake, an intercalated stratum of contorted ist, N. 22° E., dip 65° E.; and west of this, beyond another estone stratum, schist N. 12°–22° E., dip 50° E., but contor-; at Arthursburg, schist and limestone N. 12°–22° E., dip E., but with undulations. At Clove Ore bed, limestone N. E., dip E. 45°; schist of west slope of the mountain between ve and S. Dover N. 52° to 60° E., dip E. varying in 1 m., tward to N. 37° E., then on descent toward S. Dover, N. 22°– E. Nearly ¾ m. N.E. of Mabbitsville, schist contorted, N. W. to N. 2° E., dip 50°–60° E.; 1 m. N.E., impure limestone, 6° W., dip 40°–50° E.; schist 2 m. W. of Wassaic N. 22° E., varying, 25°–30° E., to nearly horizontal; near Wassaic, ist N. 17°–22° E., dip 60°–70°; 2½ m. W. of Mabbitsville, at lbrook, schist N. 19° E., dip 70° E. At Millerton, limestone illage, near upper railroad depot, nearly horizontal, dipping 10° 20° E., strike about N. 12° E.; ½ to 1½ m. west of Millerton, ıg R.R., N. 10°–20° E., dip 5°–20° E., to horizontal, and 10° W.; 2 m. west of M., on R. R., another large bed of lime-ıe; ½ to ½ m. W. of M., schist (a thin, slivery, blackish slate) rlying the limestone nearly horizontally (as seen in section on west); 1½ m. to 2 m. north of west of M., on R. R., the same ist, nearly horizontal over the limestone (as seen in section); to 3 m. northwest of M., along R.R., schist of Winchell's untain N. 20°–28° E. dip, 20°–50° E., the least on the east. 'o and one-half m. south of Boston Corners, schist of eastern ɪe of Winchell's Mtn., N. 12°–17° E., dip 20°–25° E., increasing 45° nearer B. C.; schist of the body of the Mtn., N. 12°–18° dip 45° E.; at Boston Corners, close to Taconic Mtn., lime-ne and schist N. 13°–14° E., dip 70° E. At Weed's Ore Pit, Southern Copake, 3 m. N. of B. C., schist N. 18° E., dip 62°–' E.; and 1 m. W., limestone N. 12°–14° E., dip 50°–60° E. At Verbank, slate N. 5° W. to 12° E., dip 50°–70° E.; lime-ne conformable to the slate, but much contorted.

The diversity in the strike near Brinckerhoff was probably ısed by the spur of Archæan rocks, which reaches from the south ırly to the place. The schist west of Millerton has much luster Winchell's Mountain, but very little farther east *where the beds ı approximately horizontal.*

The quartzyte near Matteawan (see p. 385 of last volume) is situated *directly east* of this place, and extends along for half a mile.

Great Central Belt, commencing at the North.—In North Salisbury, Conn., ½ m. south of Massachusetts boundary, just east of the road nearest to the foot of the mountain, limestone N. 10°–12° E., dip 50°–60° W.; 1 m. to 2 m. farther south, N. 6°–12° E., dip 45°–60° W.; ¾ m. east of the first of these loc., dip 50° E.; and 1¼ m. E., N. 15°–25° E., dip 50°–55° E.; at head of Wash-nee lake, limestone N. 16° E., dip 45°–55° E.; ¾ m. S., N. 3° E., dip 40°–50° E.; at Chapinville, limestone N. 9° W., dip 20°–25° E.; 2 m. N. of Salisbury, mica schist, N. 15° E., 50°–60° E. In Lakeville, on lake, limestone N. 23° W., dip 50° E., and east of lake, limestone N. 18°–23° W., dip 20°–25° E.; 2½ m. east of Millerton, mica schist N. 8°–22° W., dip mostly 40° E.

In Sharon, ½ m. E. of Sharon Post Office, limestone N. 20° E (average) dip 60° E.; 1½ m. to southeastward, gneiss, N. 26° E., dip E.; 2 m. to southward of Sharon, *quartzyte*, N. 26°–31° E., dip 60° E., the quartzyte in part schistose and containing some silvery mica, in other parts to eastward feldspathic and passing into granulyte, and the quartzyte and gneiss lying conformably along the east border of the limestone.

East of Wassaic, N. Y., limestone N. 12°–22° E., dip 45°–50° E.; 1½ m. S., limestone N. 26°–27° E., dip 55° E.; east of last, *quartzyte* (at quarry) N. 4° W., 40°–45° W. East of Dover Plains, 1 m., limestone N. 10°–20° E., dip 50°–60° E.; ½ m. farther east, and just east of the limestone area, quartzyte N. 10°–21° E., dip 50°–60° E.; ⅛ m. S.E., gneiss N. 10°–11° E., dip same. At South Dover, near R. R. station, limestone N. 20° E., dip 70°–80° E.; one mile north of Pawling, limestone N. 7° E., dip 70° E.; 1 m. E. of same, gneiss and mica schist N. 7° E., dip 70°–80° E., near Pawling Station, limestone N. 19° E., dip 60°–70° E.; and ½ m. to 1 m. W., same N. 2° E., dip 40°–70° E.; then nearly horizontal with dip westward and again eastward, and then 40°–50° E. prevails; 2 m. W., gneissoid mica schist or micaceous gneiss (just W. of a limonite ore bed) N. 2°–10° E., and varying to N. 32° E., dip 50° E. About Towner's (near the Archæan), gneiss underlying conformably the limestone, with wide variations in strike, N. 68° W., dip 40° E., but in hill to W., N. 38° W. to N. 88° W., dip E., about 40°; 1 m. S. of T., in the marshy valley, near a red house, the limestone interstratified with the gneiss, N. 32° E., dip 60° E. (the vicinity of the Archæan accounts for the contortions); ¼ m. N. of Dykeman's, whitish gneiss, N. 17° E., dip 70°–80° E.

The limestones of Dutchess County are distinctly fossiliferous only where, besides being imperfectly metamorphic, they do not contain seams of quartz, but instead calcareous seams, if any, as well as calcareous fossils. The quartz seams imply greater heat for the metamorphism; and when the penetrating moisture was thus rendered siliceous, the shells have been left as thin pieces of quartz, usually with little of the original form. The schist adjoining also has often its quartz seams or veins.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

*On the Action of Isomorphous salts in exciting the Crys-
tion of Supersaturated Solutions of each other.*—Thompson
udied the action of solid salts upon supersaturated solutions
er salts, isomorphous with these, to ascertain whether crys-
tion would be induced. When the salt used as the nucleus,
l as the other, formed a supersaturated solution, such a
on of the latter was placed in a small flask and a correspond-
lution of the former, placed in a thin bulb tube was intro-
into the flask, the liquid having been boiled and the mouth
with cotton. The liquid in the flask was then boiled and
uth was also stopped with cotton. After cooling, the liquid
bulb tube was first caused to crystallize by a fragment of
me salt. It was then lowered into the liquid in the flask,
roken and the result observed. If the liquid in the bulb
ot a supersaturated solution, it was allowed to crystallize
ling before the bulb was broken. Another method was to
place of the bulb, a doubly bent syphon tube containing
citing liquid. In some cases a thoroughly washed nucleus
ropped into the supersaturated solution. The results showed
$IgSO_4(H_2O)_7$ was made to crystallize by the correspond-
lphates of zinc, nickel, cobalt, iron and magnesium, by
$_4(H_2O)_6$, $FeSO_4(H_2O)_7$, and $CoSO_4(H_2O)_7$; while MgK_2
$_2(H_2O)_6$, $Na_2SO_4(H_2O)_{10}$, $Na_2S_2O_3(H_2O)_5$, NaCl and glass
o action. $Na_2SO_4(H_2O)_{10}$ was made to crystallize by Na_2
$H_2O)_{10}$ and $Na_2CrO_4(H_2O)_{10}$, but not by $MgSO_4(H_2O)_7$,
O_4, $Na_2S_2O_3(H_2O)_5$, $Na_2HPO_4(H_2O)_{10}$, KCl, NaCl,
$_2$, $NaI(H_2O)_4$ or glass. Chrome and iron alums caused
ium aluminum alum to crystallize, while NaCl, FeS_2 (in
and Fe_3O_4 (in octahedrons) did not. In the case of mix-
there are two cases: A, when the mixture contains two
which are not isomorphous; and B, when the two salts are
rphous. In the former case, (*a*) sudden crystallization takes
with a deposit only of the salt forming the nucleus; (*b*) the
both salts being deposited but the one like the nucleus pre-
rating; and (*c*) the nucleus may slowly grow by accretion
own salts from the solution. In the latter, (*a*) sudden crys-
tion takes place, both salts being deposited apparently in
tio in which they exist in the solution; and (*b*) slow crys-
tion goes on, the least soluble salt being deposited. This
case shows that there is a regular gradation from super-
ted to ordinary crystallization.—*J. Chem. Soc.*, xxxv, 196,
1879. G. F. B.

On Ozone and the Silent Electric Discharge.—Berthelot
bserved some curious anomalies in the action of the silent
ic discharge itself or of the ozone which it produces, upon
cal combination. Hydrogen and oxygen, for example,

mixed in the proportion of 2 : 1, do not combine under these circumstances even when submitted to the action of the silent discharge for several hours, with a spark in ordinary air of 7 or 8 cm. This result is the more remarkable, since oxygen under these conditions combines readily with the metals, sulphurous oxide, arsenous oxide, iodine, and even nitrogen. Carbonous oxide on the other hand, mixed with half its volume of oxygen, left after twelve hours only eight per cent uncombined, mixed with two per cent of oxygen; the rest having united with the mercury. A part of the CO had formed a brown oxide C_2O_2. Carbon dioxide under the action of the silent discharge, in a space free from oxidable bodies gives results which lead the author to suspect the existence of a percarbonic oxide CO_3. In one experiment, after twelve hours, sixteen per cent of the CO_2 was decomposed, and a gas was formed which attacked mercury and oxidable bodies with vigor. This cannot be ozone since in that case from thirty to forty-one per cent of the oxygen set free would have been converted into this substance, an unheard of proportion. The new body has not been isolated.—*Ann. Chim. Phys.*, V, xvii, 142, May, 1849. G. F. B.

3. *On the Occlusion of Hydrogen by Copper.*—Johnson has re-examined the result deduced by him from his earlier experiments, that metallic copper occluded an amount of hydrogen which might cause serious error in organic analysis; this result having been questioned by Thudichum. The copper to be tested was oxidized at the blowpipe, reduced in hydrogen, allowed to cool in that gas, the H displaced from the tube by dry air, the metal re-oxidized in a current of dry air, the water produced being collected in a weighed tube containing pumice moistened with sulphuric acid, special precautions being taken to exclude extraneous moisture. It was found that this occlusion actually took place, and that the pulverulent metal formed from the oxide reduced on the surface of the copper was most active, the amount occluded diminishing progressively as the metallic powder becomes denser by successive heating. A carefully conducted experiment showed the occlusion of 0·035 gram of hydrogen by 100 grams of copper. But curiously enough, it appeared that the finest precipitated copper oxide yields a finely divided metal on reduction, which does not occlude hydrogen. Moreover the author found that the copper thus hydrogenized, reduced potassium chlorate to chloride, and when ignited in CO_2 reduced it to CO. Heated in CO or in N, all its occluded hydrogen is given up. Heating alone in a vacuum does not set free the gas. The author therefore concludes that it is unsafe to employ copper freshly reduced in hydrogen for the reduction of oxides of nitrogen in organic analysis unless the metal be previously ignited in nitrogen gas.—*J. Chem. Soc.*, xxxv, 232, May, 1879. G. F. B.

4. *On the Composition of Charcoal from pure Cellulose.*—Berthelot has examined the charcoal produced from the pith of the spindle tree (*Euonymus*) in the process of carbonizing this

word for the manufacture of gunpowder. This charcoal therefore was made out of contact with the air and with the pyrogenic reaction products. After drying at 100°, during which it lost nine per cent, it was burned in a current of oxygen, and left 3·5 per cent of ash. The combustion afforded: carbon 73·6, hydrogen 2·2, potassium 2·1, oxygen 21·8, giving the formula $C_{24}H_{8}KO_{27}$; though no formula is actually probable of course. This charcoal contains oxygen much in excess of that which a simple hydrate of carbon requires, its amount being surprising. This is one of those special compounds of high molecular weight formed by successive condensations, carbon itself being the limit which is finally reached.—*Ann. Chim. Phys.*, V, xvii, 139, May, 1879.

G. F. B.

5. *On the Substitution derivatives of Nitrogen trichloride.*—KÖHLER has investigated the bodies discovered by Wurtz and considered by him derivatives of nitrogen trichloride. Tschermak first established the correctness of this supposition by acting on dichlorethylamine with zinc-ethyl and obtaining triethylamine. The author has confirmed these results and has produced the corresponding methyl compound, dichlormethylamine $N.CH_3.Cl.Cl$. It is a gold-yellow liquid, irritating to the eyes, boiling between 59° and 60°, and quite permanent. Köhler hopes by its means to produce the azo-compounds of the fatty series, by a reaction analogous to that by which phosphobenzene is produced from phosphenyl chloride and phenylphosphine.—*Ber. Berl. Chem. Ges.*, xii, 770, May, 1879. G. F. B.

6. *On the Preparation of pure Cuprous chloride.*—The difficulties in the preparation of pure, dry and white cuprous chloride are well known. ROSENFELD having observed that the oxidation product of this body is converted into copper acetate by glacial acetic acid, while the cuprous chloride itself is only difficultly soluble in this liquid, has suggested a new method of preparation. By passing SO_2 gas into a mixture of equal molecules salt and copper sulphate in solution, the cuprous chloride is precipitated. This is collected on a vacuum filter, and washed first with SO_2 solution till this comes through colorless, and then with glacial acetic acid till the product appears perfectly white. The acid is drawn out of the precipitate by the vacuum, and this is pressed between paper and dried on the water bath, or in the air at ordinary temperatures. Thus made, it is a pure white powder composed of colorless tetrahedrons upon which strong sunlight has no action. Strong sulphuric acid scarcely acts on it. In the dark, dilute nitric acid is also without action; but when suspended in nitric acid diluted with six parts of water, the cuprous chloride is extraordinarily sensitive to light, the crystals becoming black with a luster like metallic copper, and suffering a true reduction.—*Ber. Berl. Chem. Ges.*, xii, 954, May, 1879. G. F. B.

7. *On the Composition of Wood.*—THOMSEN, noticing the considerable quantity of extract yielded to dilute sodium hydrate solution by birch wood, which extract was precipitated again

either on neutralizing with an acid or on the addition of alcohol, has made a systematic examination of the substance thus obtained. For this purpose sawdust from birch wood was treated with soda solution of 1·1 sp. gr. for 24 hours, diluted and filtered. The brown solution on saturation with H_2SO_4 deposited a whitish gelatinous precipitate. Alcohol acted similarly but the filtration was easier. After washing with alcohol and drying at 100°, it constituted fifteen per cent of the wood used. As it acts like a gum the author proposes to call it wood-gum. Subsequently a purer product was obtained by previously treating the wood with ammonia, and then with the soda. It afforded on analysis carbon 44·6, hydrogen 6·4, corresponding to the formula $C_6H_{10}O_5$. Comparative examinations of the quantity of this substance in various woods were then made, and the kinds examined by the sulphuric acid method arranged themselves in the following order in this respect: birch, ash, alder, cherry, white beech, oak, pear, beech, elm, willow, horse-chestnut, maple and pine, the last yielding only traces. The quantity was greater the nearer to the center of the tree the specimen was taken. Wood-gum is insoluble in cold water, but dissolves in fifty parts of boiling water, gelatinizing on cooling. It does not ferment after boiling with dilute sulphuric acid, does not reduce the copper test, and rotates to the left.—*J. prakt. Ch.*, II, xix, 146, March, 1879. G. F. B.

8. *Dust Figures produced by Sound Waves.*—Her. K. H. Schellbach and E. E. Boehm extend the work of Professors E. Mach and Fischer on the reflexion and refraction of sound contained in Pogg. Ann., cxlix, p. 421, 1873. By the use of fine coal dust strewn upon paper they were enabled to trace the effect of sound waves. When the prepared paper was placed beneath the spark produced by a Holtz machine, provided with large condensers, concentric rings appeared which were due to the sound waves. When the spark was produced between converging planes the waves of reflection of sound were clearly evident upon the prepared paper. The various theoretical laws in relation to caustics by reflection from spherical surfaces; the reflection from one focus of an ellipse to the other and the principle of Huggens in regard to the reflection of waves of light were distinctly shown to hold good experimentally in the case of sound. These experiments are analogous to those of Toppler, published many years ago. The latter physicist, however, gives a much more interesting way of studying sound waves by actually illuminating, so to speak, the wave itself.—*Annalen der Physik und Chemie*, No. 5, 1879, p. 1. J. T.

9. *Continuous Spectrum of Electric Sparks.*—Professor Anton Abt shows that the spectrum of the electric spark between two conductors in water and other fluids is a continuous one, and does not contain the lines which are apparent in the spectrum taken between metallic conductors in air. He attributes the continuous spectrum to the particles of the metals of the electrodes which are raised to a white heat but not to the gaseous condition which pro-

duces bands, when the spectrum of the spark in air is perceived.—*Annalen der Physik und Chemie*, No. 5, 1879, p. 159. J. T.

10. *A New Theory of Terrestrial Magnetism.* — Professors PERRY and AYRTON have proposed the following theory of terrestrial magnetism, which is based upon the experiments of Professor Rowland, of Johns Hopkins University, Baltimore, carried out in Professor Helmholtz's laboratory. In these experiments Professor Rowland showed that a magnetic needle is deflected by the movement of a static charge of electricity. Professor Rowland detailed to the writer of this notice, two years ago, in Cambridge, the same theory which is now proposed by Professors Perry and Ayrton. The theory is that the revolution of the earth beneath the electrical charge originally and at all times present in the atmosphere may and is sufficient to account for the magnetism of the earth.

Professors Perry and Ayrton have submitted the matter to calculation, and find that the difference of potential between the earth and space necessary to produce a distribution sufficient to produce the observed magnetic effect can be represented by fifty-four million Daniell cells. They prove, according to this theory that "if the earth be electrified, it must, from its very rotation, quite independently of all other bodies in the universe, be magnetic; and if it consist of a shell of iron, thick or thin, then that the law of distribution of magnetism produced by this electrical charge in mechanical rotation, will be identically that given by Biot; and, lastly, if the earth were wholly of iron, a difference of potentials of about fifty-four million volts between it and space would be sufficient to produce the necessary amount of charge.—*Phil. Mag.*, No. 45, p. 401, June, 1879. J. T.

11. *Experimental researches in Pure, Applied and Physical Chemistry;* by E. FRANKLAND, Ph.D., D.C.L., F.R.S., &c. 1047 pp. 8vo. London, 1877. (John Van Voorst).—Dr. Frankland has made a most acceptable gift to chemical literature and especially to the convenience of students, by bringing into one volume his numerous memoirs, extending over thirty years and scattered in various Journals and Transactions. The sixty-four memoirs here reproduced are pretty equally divided between pure, applied and physical chemistry. The rapid and fundamental changes in chemical philosophy and notation, which have occurred during the period covered by Dr. Frankland's memoirs, changes toward which his own researches have largely contributed, have required a thorough revision of the notation of his earlier papers. The volume opens well therefore with a reproduction of his "Contributions to the Notation of Organic and Inorganic Compounds" from the Journal of the Chemical Society (1866). The nine chapters devoted to pure chemistry contain some of the most important researches which mark the progress of discovery in organic chemistry. For example, the three memoirs on the "Isolation of the Alcohol Radicals," the nine memoirs on the "Synthesis of Organo-metallic bodies," the two synthetical researches on acids of the

lactic series, one on the acids of the acrylic series, and four on fatty acids. Each of these series of researches forms a continuous work and is prefaced by an analytical *resumée*, prepared for this volume, giving the author's mature views on reviewing the several subjects in the light of our present knowledge.

The experimental researches on various subjects in applied chemistry are full of interest; they include among the subjects, artificial light; the so-called hydro-carbon gas process; the gas supplied to London in 1851 and 1876; contributions to the knowledge of the manufacture of gas; on the igniting point of coal gas; and on magnesium as a source of light; all of which are replete with valuable data both theoretical and practical. The chapter on drinking water embraces, in six memoirs, a mass of valuable original research, as also does that on the purification of foul water, discussed in five memoirs. Every student of public hygiene as well as chemists will profit by the study of these chapters.

The memoirs on the influence of atmospheric pressure on combustion, and on the spectra of gases and vapors form the opening chapters in the section on Physical Chemistry, which is continued in memoirs on the source of muscular power and on climate.

Authors like Graham and Frankland (and we may add Rumford, whose collected memoirs the American Academy at Boston have lately made accessible) promote the progress of science not alone by the actual work done by them in original research, but possibly quite as much by the unconscious influence such collected memoirs exert by furnishing models of investigation worthy of imitation and stimulating others to a generous rivalry. B. S.

12. *A Guide to the Qualitative and Quantitative Analysis of the Urine, &c.;* by Drs. NEUBAUER and VOGEL, with a Preface by Professor FRESENIUS; translated from the seventh enlarged and revised German edition by Dr. Elbridge G. Cutler of Massachusetts General Hospital and assistant in the Medical School of Harvard University. Revised by Dr. Edward S. Wood, Professor of Chemistry in the Medical School of Harvard University. 551 pp. 8vo. New York, 1879. (William Wood & Co.).—A new translation of Neubauer and Vogel's well known work, which, since 1854, has passed through seven editions (to 1875) in the German, is a welcome and important contribution to the study of this special department of Chemistry. The translation of this work published by the Sydenham Society in 1863 was from the third edition, since which time very important changes in the text with numerous additions have rendered a new translation essential. No other work in the English language treats this department of chemistry in so systematic and thorough a manner, and it is risking little to say that this translation will come into general use wherever medical chemistry is taught as well as among chemists and physicians whose investigations demand a knowledge of the best methods of analysis and pathology in this direction. B. S.

13. C. GREVILLE WILLIAMS, F.R.S., of London, has just added a *Supplement to his Hand-book of Chemical Manipulation.* 88 pp.

8vo. London, 1879. (Van Voorst.)—This handbook, well known to chemists, contains notices of new methods of manipulation, with twenty-three figures of apparatus adapted for improved laboratory practice, and mostly selected from contemporary literature, with some things not before published. The selection is generally judicious and the supplement will be found useful in every working laboratory. B. S.

14. *Specific Gravity of the Vapors of Phosphoric Pentasulphide and Indium Chloride.*—VICTOR MEYER and CARL MEYER have determined the specific gravities of these vapors by the method of displacement which they devised and had previously described. They have found, in two determinations for the vapor of phosphoric pentasulphide, the specific gravities 110·1 and 110·7 when $H_2=1$ and for that of indium chloride the value 113·6. As the half molecular weight of P_2S_5 is 111, it is evident that this compound—unlike P_2Cl_5—is converted into vapor without disassociation; and since the specific gravity of the vapor of indium chloride corresponds very closely to that required for $InCl_3$, it would appear that this compound ought not to be classed with the sesquichlorides Fe_2Cl_6 and Al_2Cl_6, as chemists have been inclined to place it since the investigations of Bunsen on the specific heat of indium.—*Ber. der Deutsch Chem. Gesellsch.*, 28 April, 1879, p. 609.

II. GEOLOGY AND NATURAL HISTORY.

1. *Die Dolomit-Riffe von Südtirol und Venetien. Beiträge zur Bildungsgeschichte der Alpen*, von E. MOJSISOVICS VON MOJSVÁR. 552 pp. 8vo. Vienna, 1878. (Alfred Hölder.)—The Dolomite region of the Southern Tyrol is well known as one of the most remarkable portions of the Alps, both in the unique beauty of its scenery, and in the variety and interest of its geological structure. The strangely picturesque and wonderfully varied forms of the dolomite mountains, sometimes in perpendicular walls, and again as sharp jagged peaks, give the region a striking character of its own. Moreover, the peculiar interest connected with the study of them, as also that of the accompanying igneous rocks and the contact phenomena involved with them, has long made it a favorite region for geological study.

The present work gives a clear, comprehensive, and, at the same time, minute description of the geological relations of the whole region by one whose long experience in the study of the Eastern Alps has thoroughly fitted him for his work. In addition to the special description of each section of the country, with the numerous cuts and profile views, the work also includes several chapters of more general interest, and one of these contains a discussion of the Permian and Mesozoic Formations of the Eastern Alps. The closing chapters give the author's views in regard to the method of formation and time of elevation of the Dolomite peaks. He adopts the view, first put out by Richthofen in 1860,

that the dolomite mountains are true *coral reefs*, and finds confirmation for it in the massive unstratified character of the rock, and the fact that while poor in fossils they yet contain more corals than any other form of organic remains.

The work is accompanied by a large and finely executed geological chart in six sheets, and is moreover illustrated by thirty photo-engravings (Albertypes) which give an admirable idea of the most striking and beautiful features of the country, and are of great service in making clear the geological descriptions. E. S. D.

2. *A Native gelatinous Silicate.*—Prof. E. Renevier has described the occurrence of a gelatinous silicate, having the composition of chabazite. It was found in small fissures in the molasse, near Lausanne, Switzerland, on the occasion of the building of a tunnel. When first taken out it was in a gelatinous state, like semi-liquid starch paste. Its color was white, translucent, its luster was greasy, and the touch unctuous. In the air it dried rapidly, and at the end of some weeks it was transformed into a soft, white, sectile mass, having some consistency, and more or less plastic. If exposed still longer it became nearly solid, resembling steatite; in this condition it had about the hardness of talc, and its specific gravity was found to be 2·08—2·10. An analysis by Prof. Bischoff, on material dried at 100° C., afforded the following results:—

SiO_2	$\text{Ⱥ}lO_3$	CaO	MgO	K_2O	H_2O
48·39	20·49	3·57	3·14	2·79	21·62=100·00

This corresponds closely with the composition of chabazite, and Renevier refers it to this species, but calls it a "mineral in an embryonic condition."—*Bull. Soc. Vaud. Sc. Nat.*, xvi, 81. E. S. D.

3. *Naturwissenschaftliche Beiträge zur Kenntniss der Kaukasusländer auf Grund seiner Sammelbeute herausgegeben*, von Dr. OSCAR SCHNEIDER. 160 pp. 8vo, Dresden, 1878.—The extensive collections in natural history, mineralogy and geology, made by Dr. Schneider in the Caucasus during the summer of 1875, have been worked over in part by himself and in part by a number of specialists, and the results are contained in the present volume. The minerals have been studied by Professor Frenzel; among other points he describes a new species under the name of *urusite*. It was found with iron vitriol and other iron salts at Tscheleken. Its characters are as follows: it occurs in rounded masses, also pulverulent and earthy. The lumps are soft and easily crushed to a powder consisting of minute orthorhombic crystals. The specific gravity is 2·22; the color is orange yellow and the streak ochre yellow. An analysis gave: SO_3 42·08, $\text{Ƒ}eO_3$ 21·28, Na_2O 16·50, H_2O 19·80 = 99·66. This corresponds to the formula $Na_4\text{Ƒ}eS_4O_{17}+8H_2O$.

4. *Mémoire sur le Fer Natif du Grœnland et sur la Dolerite qui le renferme* par J. LAWRENCE SMITH. (Annales de Chimie et de Physique, V, xvi, 1879).—The native iron of Ofivak, Greenland, was discovered by Professor Nordenskiöld in 1870, and by him described as of meteoric origin; later writers, however, have

been inclined to refer it to a terrestrial rather than to a cosmical source. This matter has been made the subject of an extended memoir by Dr. Lawrence Smith, and his conclusion that the iron is in fact terrestrial is so thoroughly proved that it can hardly be questioned in future. Dr. Smith describes in detail the several varieties of the iron and gives analyses of them; he has also investigated the dolerite in which the iron occurs both chemically and microscopically, and all the points are discussed with admirable thoroughness. The remarkable disintegration which has reduced many of the seemingly solid masses of iron to a fine powder, Dr. Smith attributes first to the loss of moisture, which results in the production of cracks in the surface, and then to the fact that the air, having access to the interior of the mass and meeting the iron in a finely divided state, rapidly causes its oxidation. An analysis of the unoxidized iron afforded the following results: G. = 6·42

Fe	Ni	Co	Cu	P	S	Cl	C (combined).
93·16	2·01	0·80	0·12	0·32	0·41	0·02	2·34 = 99·18

Other varieties of the iron associated with the dolerite gave somewhat different results, but all showed the presence of both nickel and cobalt. Associated with the iron in the dolerite were the following minerals: niccoliferous pyrrhotite, graphite, hisingerite, magnetite, spinel and corundum. Of these the graphite is the most interesting in relation to the explanation offered by Dr. Smith for this extensive occurrence of native iron. He argues that the basaltic rocks of Northern Greenland at the time of their eruption must have forced their way through lignitic miocene beds, setting free by their heat vast amounts of gaseous hydrocarbons, which would have exerted a powerful reducing effect on the iron oxides in the basalt. This would explain the considerable amount of combined carbon in the iron and also the large amount of graphite present in the rock. Dr. Smith has also reinvestigated some of the other so-called meteoric irons of Greenland, found at various localities for lat. N. 63° to 76°. He concludes that they are all similar to the Ofivak iron, and probably, like it, are of terrestrial origin.

5. *Jarosite* (*with Gold*).—This rather rare species occurs quite abundantly in the quartz veinstone of the Vulture gold mine in Arizona, whence I have received it from Mr. G. A. Treadwell. It fills cavities formed from the oxidation of pyrite. Fine transparent, yellow and dark brown, rhombic crystals—almost microscopic, are alternated with cryptocrystalline masses, in which, occasionally, are seen small brilliant particles of gold. The Vulture vein is enclosed in walls of a schistose gneiss or mica schist, and the atmospheric decomposition of the sulphide has been so complete that at a depth of nearly 300 feet only cubical cavities and a curious structure due to the removal of pyrite are observed, and the mine at that considerable depth is *completely dry.* R. S.

6. *The Botanical Text-book.* (*Sixth edition.*) *Part I. Structural Botany, or Organography on the basis of Morphology. To*

which is added the Principles of Taxonomy and Phytography, and a Glossary of Botanical Terms; by ASA GRAY, LL.D., etc., Fisher Professor of Natural History (Botany) in Harvard University. 442 pp. 8vo. New York and Chicago. 1879. (Ivison, Blakeman, Taylor and Company.)—The first edition of Dr. Gray's work was published in 1842: the year in which the author entered upon the duties of the Fisher Professorship at Cambridge. Six years before this, however, he had published a work entitled *The Elements of Botany*, which may be fairly regarded as a still earlier edition of the Text-book. The plan of this early work was generous in its scope, and was philosophically developed. A morphological basis was adopted as the only safe one on which to build, and upon this a symmetrical superstructure was erected. It was no ordinary sagacity which led a young botanist, without experience in teaching, to select a method which has needed no essential change for forty years, and which is to-day generally accepted as best adapted to elementary and advanced instruction. The "Text-book," which was developed from the earlier "Elements of Botany," has passed through several editions, the last of which, published in 1852, is widely known under the title, "Structural and Systematic Botany." A still further development of the plan selected at the outset, necessitated a division into separate volumes, and it is of this that mention must now be made. The present edition of the Text-book has outgrown its former limits and is to be embodied in four volumes. The first, devoted to Organography, upon the basis of Morphology, has just been published; the three remaining, to follow after a time, are to comprise respectively, Histology and Physiology, Cryptogamic Botany, Special Morphology of the Natural Orders. Other hands are to aid in preparing the second and third volumes. The arrangement of the early chapters in the present volume is nearly the same as that of former editions, but every section has been rewritten and considerable new matter added. Important changes have been made in the chapter on Inflorescence, or Anthotaxy. For the old names of the two types, the new ones, Botryose and Cymose have been substituted, and the forms of the latter are for the first time in English placed upon the satisfactory basis suggested by Eichler. The terminology of cymose clusters has, until recently, been much neglected, and has given rise to unnecessary confusion. An analytical table of the special kinds of definite, indefinite and mixed inflorescence is given at the end of the chapter, and will be found useful by students.

The sections devoted to the flower have undergone very great modifications. The deviations from the type-flower are discussed more fully than in any former edition, and the adaptive structures are described with considerable minuteness. It would be difficult to find a more succinct exposition of the mechanism of intercrossing than Dr. Gray has given in section IV. The special morphology of the stamens and pistil has been revised throughout and more copiously illustrated. It is instructive to observe how little

ìray's opinions respecting some mooted points of this subject changed in the successive editions of the Text-book; in the nt issue the author cites with quiet satisfaction the freshly vered and weighty evidence in support of his early views. dheres to his well-known belief, now well established, that pla- ə belong to carpels and not to the cauline axis. He adopts heory that ovules answer to leaf-lobes peculiarly transformed, › outgrowths of a leaf, whether from its edges or surface. ɜr fruits and seeds, little new matter has been added, except ful synopsis of simple fruits.

.us far the work has dealt with Morphology and adapta- : the last part of the volume is devoted to Taxonomy. presentation of the principles of classification may be r considered the most important chapter in the work, and an act must be made almost in the author's words. Holding iew that plants do not rise high enough in the scale of being ach true individuality, the author takes as the analogue of nimal individual, the cell in the lowest grades of vegetable the phytomer (*phyton*) in the higher. "In botanical descrip- and classification, by the individual is meant the herb, shrub, əe, unless otherwise specified." "Species in biological natu- istory is a chain or series of organisms of which the links or ›onent individuals are parent and offspring." "The two ele- s of species are: 1, community of origin; and, 2, similarity e component individuals. But the degree of similarity is ex- ely variable, and the fact of genetic relationship can seldom tablished by observation or historical evidence. It is from ikeness that the naturalist ordinarily decides that such and individuals belong to one species. Still the likeness is a con- əuce of the genetic relationship; so that the *latter* is the real lation of species." Variation within the species is next dis- ›d, and it is shown that only observation can inform us how ı difference is compatible with a common origin. The gen- result of observation is that plants and animals breed true generation to generation within certain somewhat indeter- .te limits of variation: that those individuals which resemble other within such limits interbreed freely, while those with r differences do not. Hence are recognized Varieties, or dif- ıces within the species, and Genera and other superior associa- ı, in which the differences are more striking. Grades denote ees of likeness or difference; but what is the explanation of likeness between species themselves? With the accepted ı respecting variation, crossing and the like, before him, the or adopts the theory of descent and limitation by natural tion, to furnish an answer to the question just asked.

ı page 330, the author says, "We have supposed . . . . that plant has an internal tendency or predisposition to vary in ; directions rather than in others; from which, under natural tion, the actual differentiations and adaptations have pro- əd. Under this assumption and taken as a working hypothe-

sis, the doctrine of the derivation of species serves well for the co-ordination of all the facts in botany, and affords a probable and reasonable answer to a long series of questions which, without it, are totally unanswerable." Following this comes a short section on the history of classification, in which is given an outline of the growth of the natural system.

The last chapter is devoted to Phytography. In this are given directions for describing plants in technical language, and for assigning names to new species in conformity with the canons of nomenclature. The fixation and precision of names is dealt with critically and at some length. Upon many points which have been held to be in dispute, the law is pretty authoritatively laid down. The important but too much neglected subject of herborizing and of preparing good dried specimens of flowering plants, is minutely and sensibly treated by Mr. Hoysradt. Directions for the formation and care of an Herbarium, and the study of dried specimens, are both as fully referred to as the space could warrant.

The volume closes with a long list of the signs and the chief abbreviations, including those of authors' names, occurring in systematic treatises. The index is an extensive glossary, in which, for the convenience of many, are given the Latin equivalents of most of the substantives and adjectives employed in botany. From the foregoing it must be seen that the present volume of the work is adapted, as we stated in the outset, to the wants of the advanced student and the working botanist alike.

G. L. G.

7. *Chronological History of Plants: Man's Record of his own existence illustrated through their names, uses, and companionship;* by Charles Pickering, M. D. Boston, 1879. (Little, Brown & Co.)—This is a quarto velume of over twelve hundred closely printed pages, about half of which were already in type before the death of the learned author, which event took place March 17th, 1878. The remainder has been printed by his widow "in exact conformity with the manuscript." The work is arranged chronologically, and begins with the year 4713 B. C., the so-called Julian Period, followed immediately by 4491 B. C., the beginning of the first Great Year in the Egyptian reckoning. The first plant mentioned by Dr. Pickering is *Artemisia Judaica* of the desert of Sinai, which he considers to be the plant of the field of Genesis ii, 5, and the second is the tree which yields bdellium, probably a palm, *Borassus dichotomus*, though possibly a species of *Balsamodendron.* The remaining plants, animals, musical instruments and metals of the antediluvians are next considered, and then, with the year 4000, Jan. 1st, the ninth generation, he passes to the colonization of Egypt, and gives first a systematic list of the plants composing the Desert Flora, and then a similar list of the maritime Mediterranean Flora. Next follow forty-six pages devoted to Egyptian hieroglyphic signs, many of them primarily significant of natural objects. Other parts of the world, with the names of kings, writers, animals, plants and arts follow

r by year, or generation after generation, nearly everything ken of being explained or interpreted by the author, until, ning page after page, we do not know which to wonder at re, his vast range of knowledge or his patience.

Iad he lived he would doubtless have written his own Preface Introduction, and in it have drawn his own general conclusions m so vast an array of facts. As it is, the work will remain, as v. Mr. Morrison says, a vast storehouse, from which other wri- s may draw the treasures with which they may enlighten their ders, or delight mankind. D. C. E.

III. Miscellaneous Scientific Intelligence.

. *Fall of a Meteorite on the 10th of May, in Iowa;* letter n Professor S. F. Peckham to the editors, dated Minneapolis, y 29, 1879.—I have the pleasure of informing you that on the h of May, a meteor exploded and fell in full daylight at . M., at Esterville, Emmet County, Iowa. One of the frag- nts, weighing about 500 pounds, fell on railroad land and was up from a depth of fourteen feet in a stiff clay soil. Another ller portion, weighing about 170 pounds, fell on the farm of A. Pingrey at a distance of two miles from the first. Many ller pieces, of a few ounces or pounds weight, were scattered the vicinity. The smaller mass fell upon a dry knoll and etrated the earth vertically to a depth of 4½ feet. The fall accompanied by a noise described as a continuous roll of nder accompanied by a crackling sound.

'hrough the efforts of Professor E. J. Thompson of our Faculty smaller mass has been obtained for the University cabinet. It rregularly square in form, about 15×18 inches and of an rage thickness of six inches.

A preliminary chemical examination shows the metallic portion onsist of an alloy of iron, nickel and tin. Full half the mass sists of stony matter, which appears in dark-green crystal- masses embedded in a light-gray matrix. When the whole owdered, a violent reaction ensues on the addition of hydro- oric acid, which is increased on boiling. The boiling acid eared to dissolve all but the gray matrix, abundance of iron sing into solution. Some of the crystalline masses are two hes in thickness, and exhibit distinct monoclinic cleavage. der the microscope in thin sections, olivine, and a triclinic lspar appear to be imbedded in a matrix of pyroxene. This rk is in the hands of Professor C. W. Hall of the University o intends to make a very thorough investigation of the optical perties of the minerals and matrix.

The chemical examination was first attempted upon a very all quantity of material, but, now that we have an ample quan- y, a complete analysis of the several minerals and the alloy l be made. A small piece of the metal polished and etched ibited the Widmanstättian figures very finely.

The larger mass is still in the hands of those who dug it from the ground, although their ownership is contested by one who claims to have contracted for the land on which it fell. Their ideas regarding its value enlarge daily, the latest announcement being, that they should feel insulted at an offer of $5,000. We trust their feelings may be spared.

2. *The supposed Meteorite of Chicago;* from a letter to the editors from Professor E. S. BASTIN, dated Chicago, May 23, 1879.— * * * I have concluded that what was claimed to be a meteorite could not have been anything of the kind. A heavy shower was in progress at the time (April 9th), accompanied by thunder and lightning, and according to all accounts at the very moment the fragments of the supposed meteorite were seen to fall, there was a vivid flash and a loud report like that of a heavy stroke of lightning. The telephone wires in a dwelling house that stood only a few yards from the place where most of the glowing fragments were seen to fall, were melted as if by lightning, and more or less disturbance was caused in other wires and telephones about the neighborhood. It is reasonable, I think, to conclude that the glowing fragments that were seen to fall to the side-walk and to rebound from the roofs of buildings were fragments of the melted wires heated to incandescence. The fragments that were picked up that evening and the next morning and were claimed to be portions of the meteorite, do not resemble any meteoric matter I have ever seen. They look very like the slag from an iron furnace, and many fragments very similar to them in appearance may be picked up almost anywhere on our streets. A chemical examination of the specimens has shown that they possess none of the characters of true meteorites.

3. *Nordenskiöld's Swedish Arctic Expedition.*—The latest advices from Stockholm (about May 30th) indicate that telegraphic information had been received from Siberia to the effect that the Vega was in winter quarters in the vicinity of Cape Serdze-Kamen (Heart-of-Stone) in about lat. 67° N. and lon. 172° W. Letters had not been received, but were expected, being on their way from Irkutsk, and were said to be of the (latest) date of February 8th, in which the professor expressed a hope to be released by the ice in May. It is hardly likely that the opportunity will occur before July, since all previous experience shows the straits to be closed or impeded up to a date between the 1st and 15th of July, and often somewhat later. The position of the party is one which is free from ice every year, and there is little doubt but that the Professor will be able to carry out his idea of circumnavigating Europe and Asia in the Vega. The party at the date of writing were all well, and the letters had reached Yakutsk *via* Kolymsk by the hands of traveling natives.

WM. H. DALL.

4. *Eruption of Etna.*—The new eruption began on the 25th of May, and on the 28th, after two days of ejections of fiery cinders making clouds and rain of volcanic ashes of great extent,

the lava was seen flowing toward Randazzo. The new craters are situated near Monte Nero, 6,232 feet above the sea, and a fissure has been opened on that side (the northwest) of the mountain. The lavas have devastated the wood of Collebasso, destroyed the vineyards, and also a bridge across the Passo Pischiaro. The rate of flow on the 30th was one meter per minute. According to reports the stream has nearly reached Alcantara.—*Nature*, June 12.

5. *Influence of Coal-dust in Colliery Explosions.*—An investigation, by W. GALLOWAY, communicated to the Royal Society, on experiments as to the influence of coal-dust in colliery explosions, has led to the conclusion that: "Although the apparatus employed appears to be on too small a scale to solve the coal-dust question unequivocally, the results obtained with it appear to be sufficiently conclusive to enable us to affirm that an explosion, occurring in a dry mine, is liable to be indefinitely extended by the mixture of air and coal-dust, produced by the disturbance which it initiates. The only means of avoiding the dangers due to the presence of coal-dust in mines appears to be to carefully and constantly water the road-ways leading to and from the working places."

6. *Elephant Remains of Southwestern part of Washington Territory.*—Mr. J. T. Donald, describes in the Canadian Naturalist, vol. ix, no. 1, the discovery of a collection of bones, over 300, in a bog, twelve feet below the surface. They are referred to *Elephas primigenius*, var. *Jacksoni* (*E. Jacksoni* of Briggs and Foster).

7. "*On the Cudgegong Diamond-field, New South Wales.*" By NORMAN TAYLOR.—The diamonds of this locality occur in river-drift, associated with gold and other gems. The drifts in the district are at least six in number. The oldest is considered by the author to be Upper Miocene or Lower Pliocene; the next middle Pliocene; others Upper Pliocene, Pleistocene, and Recent. Between the Middle and Upper Pliocene flows of basalt lava took place which have sealed up much of the older drifts. Diamonds are found in the oldest drift and, probably by derivation from it, in the newer. Gold, metallic iron, wood, tin, brookite (?), iron-sand, quartz, tourmaline, garnet, pleonast, zircon, topaz, sapphire, ruby, and corundum are also found. The author then considers the question of whether the diamonds are derived from some of the igneous or sedimentary formations (from Upper Silurian to Mesozoic) which have contributed to the drift; and concludes, from a variety of reasons, that the diamonds have been formed *in situ* in the older drift.—*Phil. Mag.*, *June*, *p.* 442, 1879.

8. *Report of the New York State Survey for the year* 1878, JAMES T. GARDNER, Director.—The third annual Report of Mr. Gardner contains a statement of the work accomplished in 1878, and is accompanied by four large maps showing the completed triangulation and its proposed extension during the coming season. The field work has been principally upon the central belt of triangles, which is to extend from Albany to Buffalo. The results

of the Survey thus far have been most important; they have revealed so great a degree of inaccuracy in existing maps of the State, that the completion of the work is seen to be a matter of the highest necessity. It is satisfactory to know that the appropriations for the present year have been already made.

9. *Transactions of the Wisconsin Academy of Sciences, Arts and Letters.* Vol. iv, 1876–77. 320 pp. 8vo. Madison, Wisconsin, 1878.—The papers in the Department of Natural Science here published include the following: Notes on Cladocera, by E. A. Birge; on the Fauna of the Niagara and Upper Silurian rocks of Milwaukee County, Wisconsin, by F. H. Day; on the extent and significance of the Wisconsin Kettle Moraine, by T. C. Chamberlin; and papers on the Mound Builders, by E. Andrews, P. R. Hoy and J. N. de Hart.

10. *Ocean Wonders, a Companion for the Seaside, fully illustrated from living subjects;* by WM. E. DAMON. 230 pp. 12mo, with many illustrations. New York, 1879. (D. Appleton & Co.)—Many facts respecting the productions of the ocean are here presented in an attractive way, but at times with an eagerness for the wonderful and sensational that carries the descriptions quite beyond the actualities of nature. We think nature's wonders wonderful enough when presented as they are without exaggeration from fiction.

11. *Paris Academy of Sciences.*—Professor Asaph Hall has been elected a corresponding member of the Astronomical Section of the Paris Academy, to fill the place made vacant by the death of M. Santini.

12. *British Association.*—The 49th meeting will commence at Sheffield on Wednesday, Aug. 20, 1879. The President elect is Professor G. J. Allman.

13. *American Association.*—The next meeting will be held at Saratoga, commencing on the last Wednesday in August. Professor G. F. Barker is President.

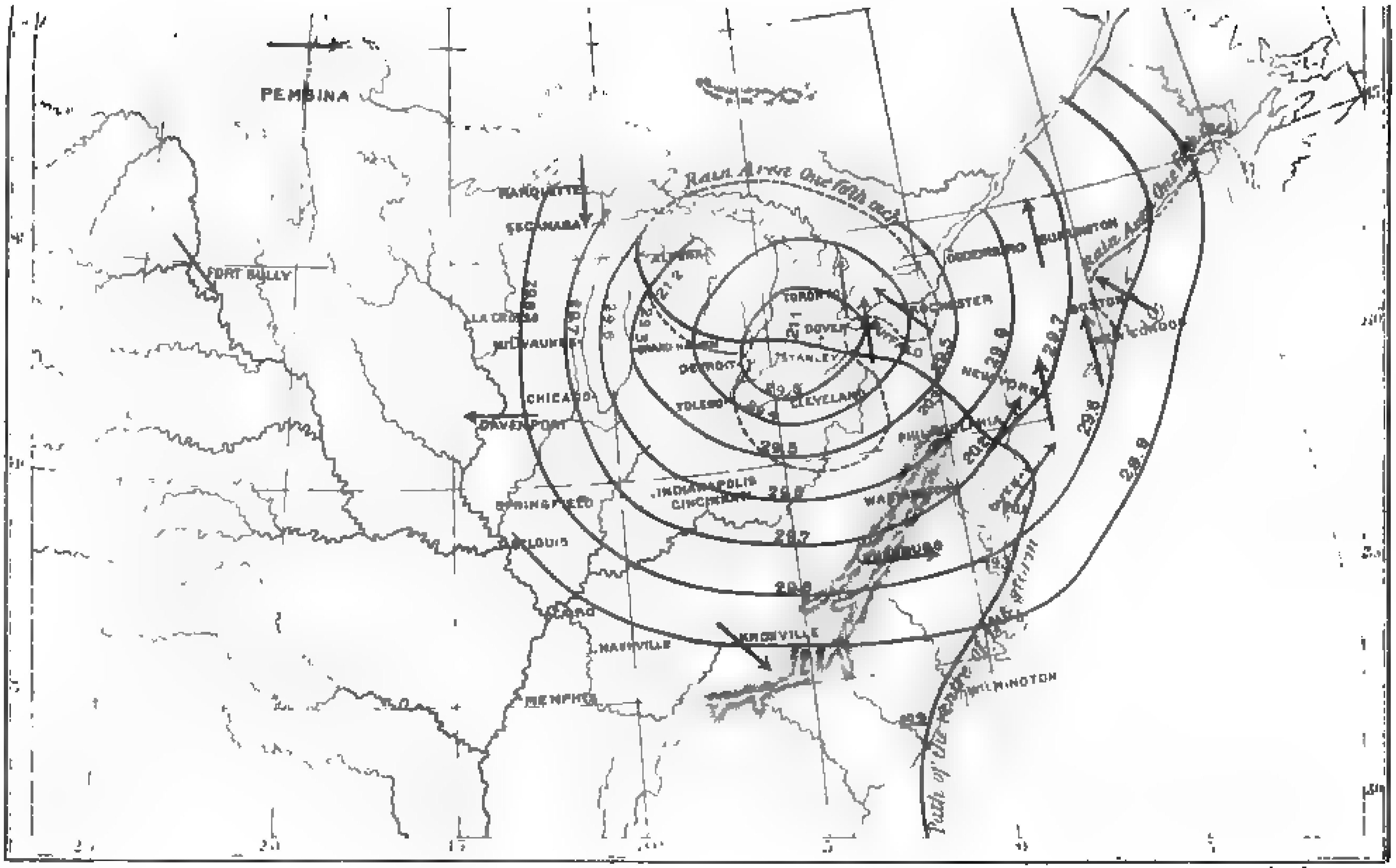
14. *A Memoir of Joseph Henry: a Sketch of his Scientific work;* by WILLIAM B. TAYLOR. 140 pp. 8vo. Read before the Philosophical Society of Washington, Oct. 26, 1878.—An excellent memoir, admirable in its full, appreciative and learned discussion of the scientific labors and discoveries of Professor Henry.

15. *Observatory on Mount Etna.*—The plans of the Mount Etna Observatory, submitted to the Italian State Secretary for Public Buildings, have been sanctioned.

16. *Early Man in Britain and His Place in the Tertiary Period,* is the title of a new work by Professor Boyd Dawkins, soon to be published by Macmillan & Co.

OBITUARY.

Prof. PAOLO VOLPICELLI, the eminent electrician of Rome, died on the 14th of April.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DAVENPORT
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NASHVILLE
MEMPHIS
KNOXVILLE
INDIANAPOLIS
CINCINNATI
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BURLINGTON
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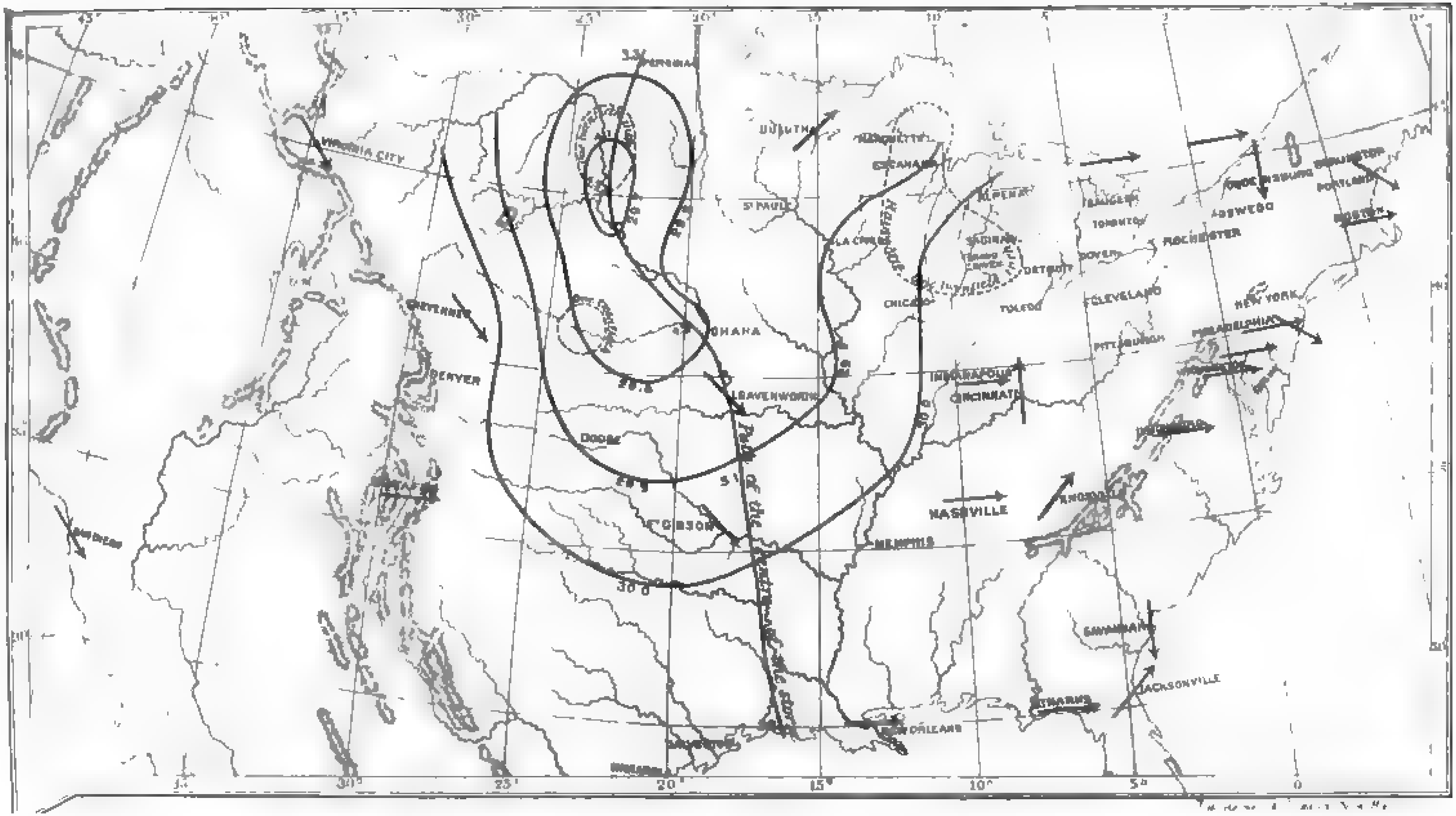
PLATE 5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ALPENA
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PORTLAND
BOSTON
NEW YORK
CLEVELAND
PITTSBURGH
PHILADELPHIA
INDIANAPOLIS
CINCINNATI
NASHVILLE
MEMPHIS
SAVANNAH
JACKSONVILLE
NEW ORLEANS
Path of the Centre of the storm

THE

AMERICAN

JOURNAL OF SCIENCE AND ARTS.

[THIRD SERIES.]

Art. XIII.—*Terminal Moraines of the North American Ice-Sheet*; by Warren Upham.

Most important additions to our knowledge of the glacial drift have been recently made by the Geological Surveys of Wisconsin* and New Jersey,† in discovering and tracing across these States distinct series of hills which appear to have been accumulated at the margin of the great ice-sheet, corresponding to the terminal moraines of alpine glaciers. The contour of these deposits is very irregular, consisting of ridges, mounds and hills, varying usually from 50 to 150 feet in height, scattered and joined to each other without order or in rudely parallel and interlocking ranges, which mainly trend in the same direction as the whole series; with many equally irregular enclosed depressions, which are bowl-shaped, trough-like, or crooked and branched, often containing ponds. The material is in some portions till, or a confused mixture of bowlders, gravel, sand and clay, entirely unstratified; elsewhere it has few or no bowlders, and consists of rounded gravel and sand worn and deposited in layers by currents of water. Different epochs in the glacial period are evidently marked by these series of hills, for that which crosses New Jersey bounds the area of striated ledges and till, which extend south to this line but not beyond it; while in Wisconsin these morainic hills are three or four hundred miles north from the extreme limit of the glacial drift. The former series is thus shown to have been accumulated when the ice-sheet had its greatest extent; but

* Geology of Wisconsin, vol. ii, 1877, pp. 205–215 and 608–635.

† Annual Report of the State Geologist for the year 1877, pp. 9–22.

the latter belongs to a time when it halted and probably reädvanced, after a period of warmer climate had caused it to make a considerable retreat. In Ohio a belt of irregular drift-hills, which appears to be the second moraine, lies about seventy-five miles north from the boundary of glacial action, indicating a convergence of the two series toward the east.

In the region traversed by the writer for the exploration of these hills, including Long Island, southern Rhode Island and Block Island, and southeastern Massachusetts, with the adjacent islands of Martha's Vineyard and Nantucket, both of these terminal moraines are finely developed, lying five to thirty miles apart. The New Jersey series, marking the farthest limit reached by the ice-sheet, continues across Staten Island to the Narrows, and thence extends in a prominent range through the middle of Long Island* and its southern branch to Montauk Point. A second series, probably contemporaneous with that of Wisconsin and Ohio, is found on the north side of this island, from Port Jefferson eastward to Orient Point, the extremity of its north branch, beyond which it forms Plum and Fisher's Islands, and enters the State of Rhode Island at its southwest corner. Thence it is well shown at a distance of one or two miles north from the shore nearly to Point Judith, where it apparently turns southward into the ocean. Twelve miles to the south the first range is again lifted into view in Block Island, a knot of very irregular drift-hills, which resemble those of Montauk.

The sea covers the next thirty miles in the line of continuation of these series of hills, beyond which both of them rise above its waves again, the northern forming the line of the Elizabeth Islands, and bending to the northeast and north on the peninsula of Cape Cod to near North Sandwich, where it turns at a right angle, and thence runs along the west-to-east portion of the Cape and extends into the ocean at its east shore. The southern moraine forms No Man's Land, the crest of Gay Head and prominent ranges of hills in the northwest part of Martha's Vineyard, extending northeast nearly to Vineyard Haven. Here this series apparently bends to the southeast, somewhat as the northern range turns at North Sandwich, but it is covered beneath plains or the sea for much of the way beyond this point. It appears unmistakably, however, on Chappaquiddick and Tuckernuck Islands, and in Saul's Hills and Sankaty Head on Nantucket.

The length of the southern moraine in its course from Sankaty Head to No Man's Land is fifty miles, and its whole extent as yet traced, to the west line of New Jersey, is about three

* This series of hills on Long Island was well described by Mather, in 1843, in the Geological Report of the First District of New York, p. 161. etc.

hundred miles. That of the northern moraine from the east shore of Cape Cod to the west end of the Elizabeth Islands is sixty-seven miles, while its total length to Port Jefferson is about one hundred and eighty miles. The distance between these series at Martha's Vineyard and westward varies from five to fifteen miles, but increases eastward to thirty miles, where they disappear finally in the Atlantic.

The Extreme Terminal Moraine.—This series of drift-hills in New Jersey begins at the Delaware River, a few miles above Easton, and extends fifteen miles east-northeast to Townsbury; then twenty miles east by Hackettstown to Dover; thence it turns to the south-southeast fifteen miles, by Morristown; and next to the south-southwest five miles to the east part of Plainfield; where, and for ten miles southeast to Perth Amboy, it forms the well-known range called Short Hills. The contour of this series of deposits is in quite irregular hillocks, with frequent enclosed hollows and ponds. Its material is stated to be coarse unstratified drift, or clay, sand, gravel, and bowlders of large and small size, mixed indiscriminately together. The profile of the country crossed by it rises from about 300 feet above sea at the west line of the State to a height of 900 feet at the mountain west of Townsbury, and to 1,200 feet on Schooley's Mountain, ten miles farther east; near Dover it has a height of 900 feet, from which it descends to sea-level at Perth Amboy.

The continuation of this moraine into Pennsylvania appears to extend southwestward, being represented by a similar series of drift-hills, lately traced by Professor Frederick Prime, Jr.,* in the Saucon valley, ten to twelve miles southwest from Easton. He also discovers at about the same distance north from Easton a second moraine, reaching some twelve miles from the Delaware River at Portland, west-southwest to Wind Gap in Kittatinny Mountain. The perpendicular distance between the latter series and the west end of that which crosses New Jersey is about eight miles.

Eastward the terminal moraine of New Jersey is distinctly continued across Staten Island, where its course is northeast twelve miles to Fort Tompkins, which is situated on its crest at the west side of the Narrows. On Long Island it forms the site of Fort Hamilton, and thence takes a quite direct east-northeast course for twenty-four miles to Roslyn; next it runs nearly due east about sixty miles to Canoe Place and the Shinnecock Hills; beyond which it bends northeast eight miles to near Sag Harbor; and thence continues, with some interruptions, in a course to the east and east-northeast twenty-five miles to Montauk Point. This moraine on Long Island consti-

* Proceedings of the American Philosophical Society, vol. xviii. p. 85.

tutes a very conspicuous line of hills, bordered along most of its course by nearly level plains on both sides. So striking is its topographic effect that it long ago came to be commonly known as the "backbone of the island."

This range is the southeast boundary of Brooklyn, Newtown, and part of Flushing; forms the heights of Greenwood Cemetery, Prospect Park, the Cemetery of the Evergreens, Ridgewood Reservoir, and Cypress Hill Cemetery; runs close north of Jamaica and Creedmoor; and holds Success or Lakeville Pond nearly at its top. Prospect Hill in Brooklyn is 194 feet; Ridgewood Reservoir, 170; Richmond Hill, 138; Success Pond, about 200; and the highest hills near this pond and to the north and east, about 250 feet above the sea. From the Narrows to Roslyn this series of irregularly undulating hills is shown by many excavations, as for cellars, streets and railroads, to be composed of till, or unstratified glacial drift, full of bowlders, most of which are rough and angular, while some have their sides planed and striated. This is the true terminal moraine of the ice-sheet.

To the east from Roslyn this accumulation of till is for the most part covered by terminal deposits of fluvial origin, which form a series of massive, irregularly grouped and connected hills and ridges of gravel and sand, distinctly stratified, often in oblique layers, and containing water-worn pebbles of all sizes up to a foot in diameter, but having few large bowlders or none. Harbor Hill, the highest point on Long Island, Jane's, Ruland's and Osborn's hills are of this modified drift; as also is nearly the entire range, both in its lower portions and at its highest summits, through a distance of more than seventy-five miles, extending from Roslyn to Napeague. Wheatly and Kirby hills are exceptions, being composed of till, while in a few other places, generally of small area, bowlders are found in abundance. The hills of Montauk, along the extreme ten miles of the island, are overspread and filled with bowlders, but are yet plainly stratified, as shown by cliffs along the shore. Heights of these hills are as follows:* Harbor Hill, half a mile east of Roslyn, 384 feet above sea; Wheatly Hill, three miles farther east, about 380; Spring Hill, two miles northeast, and Kirby Hill, three miles east from last, each about 350; Jane's Hill, the highest of the West Hills, 354; the Dix and Comac Hills, about 250; Pine Hill and Mt. Pleasant, west of Ronkonkoma Lake, about 200; the Bald and Selden Hills, 200 to 300; Ruland's, the highest of the Coram Hills, 340; Homan's Hill, north of Yaphank, about 250; Terry's Hill, south of Manorville, about 175; Rock and Canada Hills, about 200; Spring

* For many of these and foregoing heights on Long Island, I am indebted to Mr. Elias Lewis, Jr., of Brooklyn, who presented a portion of them in this Journal, III, vol. xiii, p. 235.

Hill, about 250, and Osborn's or Bald Hill, 293, the last two being a few miles southwest from Riverhead; the East Hills, and the range onward to Canoe Place, 150 to 200 feet; Sugarloaf, the highest of the Shinnecock Hills, 140; the Pine Hills, 150 to 250, reaching their highest elevation three miles southwest from Sag Harbor; Stony Hill, a mile northeast from Amagansett, 161; Napeague Hill, the highest of the Nommonock Hills, at the west end of Montauk, 135; the Hither Wood Hills, two miles east from last, about 200; the Rocky Ridge, east of Fort Pond, culminating in Fort Hill, about 150; Signal Hill, highest point of the Shagwannock Hills, east of Great Pond, about 150; east of Oyster Pond, about 100; Montauk Point, about seventy.

Depressions of fifty to one hundred feet below the highest portions occur frequently in this line of terminal deposits. That passed through by the railroad a mile southwest from Syosset, is about 140 feet above sea, being of nearly the same height with the plains at the south and north. Lake Ronkonkoma, the largest body of fresh water on the island, lies exactly in the course of this series of hills. Its area is stated to be about 460 acres; its height, fifty-four feet above sea; and its extreme depth, eighty-three feet. The only stream that crosses the line of this moraine on Long Island is Connecticut River, which rises on its north side and flows southward at the west base of Homan's Hill, its valley being here about fifty feet above sea. A few miles farther east, between Yaphank and Manorville, the railroad crosses this line on continuous plains about seventy-five feet above sea; as also does the Sag Harbor branch a few miles southeast from Manorville. The isthmus of Canoe Place, which joins the south branch to the main island, is composed of gravel and sand, less than a quarter of a mile wide and rising only twenty feet above sea-level. The portion of this moraine which occupies the next three or four miles eastward is widely famous under the title of Shinnecock Hills. Though comparatively low, they have been more noticed than other portions of this range, because the traveler finds his road winding among their irregular hillocks, knolls, ridges and hollows. They are better seen, also, because not covered by woods, which clothe the higher hills of this series extending from them to the west and northeast. Their material, as of the series generally from Harbor Hill to Amagansett, is irregularly stratified gravel and sand, with occasional bowlders, which here vary in size up to a diameter of fifteen feet. The roads from South Hampton to North Sea, from Sag Harbor to East Hampton, and thence to the Springs, cross the morainic line at depressions which are occupied by nearly level plains about forty feet above sea. The longest interruption in this series of

hills on Long Island is at the low tract of recent beach sand and marsh called Napeague, four or five miles in length and nearly two in width; beyond which are the pastured uplands of Montauk, extending ten miles, with depressions to sea-level at Fort and Great Ponds.

The cliffs on the south shore of Montauk, twenty to one hundred feet high, are constantly undermined by the sea and present fine sections, composed of stratified gravel, sand and clay, the latter usually containing intermixed gravel, while in most portions of all these beds occasional and sometimes frequent bowlders, up to three or more rarely five to ten feet in diameter, are embedded. No unstratified deposits were found in an examination of these cliffs for nearly seven miles, from Fort Pond to the light-house. The contour of this peninsula is very irregular, with many small ponds and swamps. Its surface is everywhere strown with bowlders, often very abundantly, so that they nearly cover the ground. These, however, very rarely exceed ten feet in diameter, being of small size as compared with the enormous blocks which are found occasionally near the north side of the island.

These accumulations of drift, reaching in an essentially continuous series of hills nearly 200 miles, from Delaware River to Montauk Point, and lying as already stated at the southern limit of glacial action, seem to be terminal deposits dumped at the margin of the ice-sheet during its period of greatest extent. The striated summits of all the mountains of New England, New York and northern New Jersey, show that the glacial mantle was at least a mile thick at a distance of 200 miles north from its southern edge. Its formation from the annual excess of snow-fall left unmelted would lead us to suppose that it would have a nearly level surface; and its motion southward, caused by the pressure of its much greater thickness far at the north, shows that these plains sloped toward their boundary. The Antarctic continent and the interior of Greenland are now covered by similar fields of ice. That of Greenland rises steeply at its edge, but after a few miles changes to a gently inclined plateau, elevated above the highest peaks of the land on which it lies, and apparently of immeasurable extent. Dr. Hayes found the angle of ascent on this plain to decrease from six to two degrees in thirty miles, at which distance he reached an altitude of about 5,000 feet. It is evident that such an ice-sheet, in being pushed over hills and mountains, must gather detritus and bowlders from them to be carried forward in its mass, which would thus become more or less filled with the material of the drift at least to the height of the peaks and ridges which it crossed. Differences of direction and angles of descent in the slopes of the surface of ice above,

due apparently to inequalities in the amount of snow-fall and of melting upon adjacent regions, were sufficient to make angles and lobes at the termination of the ice-sheet, and also doubtless caused downward and upward currents, by which much of the drift gathered while crossing a nearly level area, would be distributed throughout the lower part of the ice, probably to the height of several hundred feet. The beds of loose material which had been produced by long-continued decomposition of the ledges or accumulated by previous glacial action, together with the thick fluviatile deposits that probably occupied the valleys, were ploughed up by this ice-sheet and thoroughly kneaded with each other. Very large amounts of detritus were also added from erosion of the rock-surface. Fragments of all sizes and in great profusion were loosened and wrenched away, while the ledges were everywhere worn and striated by bowlders and pebbles, which were rolled and dragged along under the vast weight of ice, breaking up and grinding themselves and the underlying rock into gravel, sand, and even the finest clay.

The material which was thus gathered, mingled and swept along in and beneath the moving ice, upon reaching its termination was accumulated in heaps and ridges of unstratified drift, full of bowlders, and identical with the till which generally overspreads the ledges and underlies the modified drift of glaciated regions. The moraines of Long Island and southern New England show the same division in the character of these unstratified deposits that appears throughout the region to the north, where the lower till, which seems to be the ground-moraine of the ice-sheet, is very hard and compact, dark and frequently bluish in color, with clayey detritus and its pebbles and bowlders planed and striated; while the upper till, commonly from one to five feet thick, appears to be material which was held in the ice-mass and dropped upon the surface at its melting, being distinguished by its comparative looseness, its yellowish color caused by the exposure of its iron to oxidation, the predominance of gravel and sand instead of clay, and by the abundance and large size of its bowlders, which have seldom been worn or rounded except by the weather.

The massive hills of gravel and sand which form so prominent a part in this series of drift deposits heaped at the terminal front of the ice-sheet, appear to have been brought by glacial rivers. The melting of the ice at and near its terminal front exposed the detritus which it contained to the washing of many rills and small streams through every summer; but before the retreat of these ice-fields under a change of climate, their melting was extended over a very wide area. Their surface was then hollowed into basins of drainage and channeled

by rivers, which became heavily freighted with the gravel, sand and clay that had been held in the ice. A large portion of this gravel and sand was laid down at the edge of the glacial sheet, where these rivers descended to the lower open area beyond; and when the ice behind them disappeared these deposits remained as hills, marking where the border of the ice-sheet was even more conspicuously than its unmodified terminal accumulations of till. The latter appear with scarcely any modified drift in this moraine from Fort Hamilton to Roslyn; but thence to Amagansett a remarkable contrast is presented, the moraine of till being nearly everywhere buried by that of fluvial gravel and sand. Bowlders in these stratified deposits appear to have been brought by ice-floes or small bergs, borne on the glacial floods. Their abundance on Montauk may indicate a slight advance of the glacial sheet during or after the deposition of the stratified beds, carrying forward a multitude of bowlders which remained on the surface of the ice because they could not be removed by its streams. At its final retreat these would be dropped, forming a deposit of upper till.

Previous to the deposition of the series of hills of modified drift which we have described, it appears that the ice-sheet reached five miles south of this line, though perhaps only for a short time. This is shown by Manetto and Pine Hills, which extend in massive north-to-south ridges from the West Hills by Melville to Farmingdale. They are composed of stratified gravel and sand with rare bowlders, and have a height which declines from 300 feet above sea at the north to 150 at the south. Three miles farther east, and separated from the foregoing by a plain about 100 feet above sea, are the Halfway Hollow Hills, of similar character and nearly equal height, extending some three miles south from the west part of the Comac Hills. Opposite to these, on the north side of the west-to-east moraine series, are two spurs of the Dix Hills, which reach three or four miles north from this series, being likewise composed of modified drift, and declining in height northward from 250 to about 200 feet above sea. All these appear to have been deposited like kames, in ice-walled river-channels formed upon the surface of the glacial sheet when it was rapidly melting. The southern ridges are thus of earlier date than the principal series of terminal deposits, while those on the north were probably formed immediately after this series during the retreat of the ice-margin.

The part of Long Island south of this terminal moraine consists of nearly level plains of fine gravel and sand, five to ten miles in width and extending a hundred miles in length. The height of their north portion at the foot of the hills varies from

ifty to one hundred and fifty feet above the sea. Thence they slope gradually to sea-level at the south side of the island. Heights upon these plains, determined by railroad surveys, are as follows: Jamaica, 40 feet above sea; Mineola, 103; Hicksville, 142; Farmingdale, 63; Suffolk Station, 90; Medford, 82. A very interesting feature of these deposits has been pointed out by Mr. Elias Lewis, Jr.,* who finds frequent ancient watercourses, fifteen to twenty feet deep, crossing these plains from the hills to the bays of the south shore; most of which are now dry, except that springs appear in them one to three miles from the coast. They are quite straight, with few tributaries, their direction being generally a little west of south. Thirty of these "plain valleys," as they are locally called, occur between East New York and Riverhead, a distance of about sixty-five miles. In some cases they continue below our present sea-level and may be traced nearly across the enclosed bays to the beach-ridge which divides them from the open ocean; showing that when these valleys were formed the sea at this latitude did not reach so high upon the land as now. The cause of this depression of the ocean we may well understand, when we consider how large an amount of water was taken from it and stored up in accumulations of ice. A different effect of these ice-sheets in high latitudes was to draw the sea by gravitation away from the equator toward the poles, making it rise much higher than now in the St. Lawrence valley and in arctic regions. The plains south of the terminal moraine, and the water-courses crossing them, appear to have been formed by the same floods that deposited the hills of modified drift along the edge of the ice-sheet. Much of their finer gravel and sand was carried forward by the descending currents and spread in these gently-sloping plains, while the channels of drainage, extending to the sea-level of that time, seem to have been made by the same waters at their lower stages.

Underlying this modified drift of the plains, and sometimes rising nearly or quite to the surface, as at the clay-beds of Bethpage, are pre-glacial formations of gravel, sand and clay, containing Post-pliocene shells and lignite in numerous fragments or occasionally in thin layers. No bowlders occur upon these plains or are encountered in digging wells, which however often penetrate to the fossiliferous beds. Below the various deposits of the terminal moraine, and under the drift upon the north side of the island, are similar beds holding recent shells and lignite. The greatest elevation at which any of these fossils have been found is in a well near Manhassett, where they had a height about 150 feet above sea.

Gardiner's Island shows a fine exposure of these pre-glacial

* This Journal, III, vol. xiii, pp. 142–146 and 215.

formations overlain by drift in sea-cliffs, thirty to fifty feet high, at its southeast shore. Here in a distance of a sixth of a mile the lower strata rise in two anticlinals, which dip at angles varying from 10° to 45°. They consist of dull-red, brown, dark and black clays, and brown, yellow and white sands. These arched strata are overlain conformably by yellow sand and fine gravel, which farther east are interstratified with layers of white and dark gray sand and dark clay. About 300 feet east from the northeast anticlinal, these later beds dip 5° to 10° eastward, and lie in the following ascending order, beginning at the upper edge of the beach: dark gray sand, nine feet, underlain a little to the west by a compact ferruginous layer one foot thick, which separates it from white sand; overlain by six feet of lighter colored sand, its upper portion filled with shells* for two or three rods, at a height which varies with the slope from 12 to 20 feet above sea; next, 10 feet of dark clay, which thins out at 100 feet to the west, but increases in thickness to the east; then, about 8 feet of coarse gravel, with angular pebbles to 1½ feet in size, becoming coarser 150 feet to the west, where it holds angular bowlders 4 feet in diameter, these covered by about 10 feet of sand; which also forms the top of this section, resting on the gravel to a thickness of about 3 feet. The coarse gravel and overlying sand appear to be glacial deposits, and these, frequently with numerous and large bowlders, form the surface of the island, rising in hills 125 feet high. The shell-bed belongs to a period immediately preceding the ice age, in which the sea here had about the same temperature as now. The variously colored anticlinal strata are older than this, but yield no fossils. They are probably of the same date with similar clays on the northeast side of the same island, on the south side of Montauk a mile west from the point, and at Bethpage; as also with the lower portion of the cliffs near Brown's Point.† Further exploration is needed to compare these with the lignitic beds of Block Island and the upturned Tertiary strata of Gay Head.

North of the extreme terminal moraine on Long Island, another series of plains of gravel and sand, varying from one mile to five miles in width, and of similar height and southward slope with those on its opposite side, extends from Syosset forty-five miles eastward to Riverhead, and thence continues along the north branch of the island nearly thirty miles more to Orient Point. The description of these plains belongs

* The fossils of this place were described by Mr. Sanderson Smith, in the Annals of the Lyceum of Natural History of New York, vol. viii, p. 149. See also this Journal, III, vol. x, p. 282. Twenty-five species are enumerated, all of which, excepting one or two of more northern range, are now found living in these waters.

† Figured by Mather in the Geological Report of the First District of New York, Plate iv.

with that of the second terminal moraine, which lies at their north side. The probable origin, relation and significance of the drift deposits in central and southern Long Island having been now pointed out, similar explanations will be found applicable to their continuation eastward and to the like series of deposits farther north, so that little more than a plain description of them will be required.

Block Island, six miles long and three and a half miles wide in its south portion, presents the next segment of the extreme moraine, which appears with the characteristic features already described for Montauk, from which it is distant about fifteen miles to the northeast. The first account of this island, by Verrazzano in 1524, says truthfully that it is "full of hills." Approximate heights of some of these are as follows: Beacon Hill, the highest point on the island, 210 feet above sea; hill one-fourth mile south, 205; Pine Hill, one-third mile northwest, 150; Sandy Hill, near Grace's Point, 105; Cherry Tree Hill, 140; Pilot Hill, 185; base of the south light-house, 152; Bush Hill, the highest in the north part of the island, 140. These are irregularly grouped, with many hollows containing ponds and deposits of peat. Sands' Pond is about 125; and Fresh and Mitchell's Ponds, about 90 feet above sea. Great Salt Pond, which lies at sea-level, contains some 1,000 acres; the contour of its bottom is found by soundings to be very uneven, like that of the adjacent land, its greatest depth being 72 feet.

The south shore of this island is a continuous line of bluffs, 40 to 150 feet high, and four miles long. At their northeast end, half a mile from the light-house, the section is upper till, two feet; underlain by typical lower till, dark, compact and full of rock-fragments, twenty-five feet, reaching to the upper edge of the beach. At 200 to 400 feet southwest from this, the section is upper till, eight feet; underlain by dark clay, stratified, fifteen feet; and this by yellowish gravel and sand, forty feet, to the beach. About a quarter of a mile thence to the southwest, the order is about five feet of stratified sand and gravel at top, with numerous bowlders; dark clay, fifteen feet; yellow sand and coarse gravel with irony layers, twenty feet; typical lower till, unstratified, about forty-five feet, to the beach. At the light-house the cliffs are 150 feet high, and consist of dark clay, stratified, with enclosed layers of gravel and sand, the clay predominating and forming three-fourths of the whole. This entire bank is stratified, often very irregularly, dipping 10° to 30° in different directions. Gravelly layers, containing pebbles up to one foot in diameter, mostly angular, often occur in thick beds of this dark clay; and occasional bowlders, up to two or rarely five feet through, are embedded in all these

deposits; as also westward where sand and gravel prevail, though the dark clay continues abundant. At one point only, about a quarter of a mile northeast from Black Rock, are red, white and yellowish clays exposed. The bank here is forty feet high, and consists mainly of the dark clay, dipping about 40° to the west, and having layers of gravel and of these brightly colored clays interstratified with it. These were probably derived from erosion of older beds, and there can be no doubt that this whole line of cliffs from the base to top was deposited at the epoch of greatest extent of the ice-sheet.

Clay Head, at the northeast shore of Block Island, also exposes a bed of typical lower till at its north end, where the section is six feet of coarse gravel at top; lower till, four feet; and stratified sand, five feet, to the beach. The highest portion of these cliffs at a half mile south rises about 100 feet, and consists of gravel, sand and dark clay, irregularly bedded and inclined often 5° to 15° in different directions, with pebbles up to one foot occurring at many places in the clayey strata. This part of Clay Head seems to be wholly of glacial origin; but earlier beds, among which are some of white clay, with red clay in small amount, form the base of the bank a third of a mile to the south.

Lignite is found abundantly for a quarter of a mile south from the breakwater in the lower part of the bank, twenty to thirty-five feet high, which forms the shore. It occurs, as at Gay Head and on Long Island, in fragments, which here vary from an inch to a foot in length, preserving the distinct grain of the wood and closely resembling charcoal; and also in layers, which are here from three inches to two feet thick, generally friable and earthy, and sometimes much like peat. These fragments and layers are found both in dark clay and in white sand; the same beds also enclose layers of gravel and thin seams of white and red clay. These beds are in some places folded and contorted, but mainly lie in anticlinals of gentle slope, capped by stratified gravel and sand with enclosed bowlders. The surface of this island is partly of the same modified drift and partly till, both plentifully strown with bowlders up to ten and rarely twenty feet or more in diameter.

[To be continued.]

ART. XIV.—*Microphotography with Tolles's $\frac{1}{75}$ inch Objective;* by EPHRAIM CUTTER, M.D.

IN his admirable report to the Surgeon General of the U. S. Army, on microphotography with sunlight in 1871, Surgeon J. J. Woodward expressed the hope that others would carry out the idea he had inaugurated for demonstrating original work. The writer fully appreciates and acknowledges the great aid of his suggestions, and if I have ventured to modify his methods it has been from the force of circumstances and peculiar obstacles to be overcome.

I think that my modifications have made the way plainer and have removed obstructions which the gentleman in question did not have to contend with. I may here remark that I can see no reason for preferring microphotography to drawing exclusively, or *vice versa;* there is no antagonism, micrology needs both methods. The history of the attempt at microphotography with the $\frac{1}{75}$ is as follows: In 1867, Dr. James H. Salisbury of Cleveland, Ohio, had a work ready for the press on the causes and treatment of consumption based on 350 cases. In 1868 I became acquainted with it. Not to enter into details it is enough to say that a yeast in the blood is deemed to be the cause. It is found a year before organic disease. Dr. Salisbury killed 104 hogs by consumption artificially induced by yeast and verified it by autopsies in all the cases. From my own knowledge the treatment based on this principle is successful beyond anything I have known before. In privately making these things known I was met with the greatest incredulity as to the evidence which was mostly micrological. In order to sustain the position of my master I took Dr. Woodward's advice and resorted to microphotography. In my labors I was warmly and generously aided by Dr. G. B. Harriman, D.D.S., of Tremont Temple, and to this gentleman I give the full share of whatever credit may have been attained in photographing with Tolles's $\frac{1}{75}$ inch objective for the first time, not but that the morphology of consumptive blood could have been photographed with lower powers, but I desired to show those interested that in elucidating the views of one who in my opinion has come nearer to the real nature of tubercle than any one before him I had employed the best instruments of precision that modern art has produced.

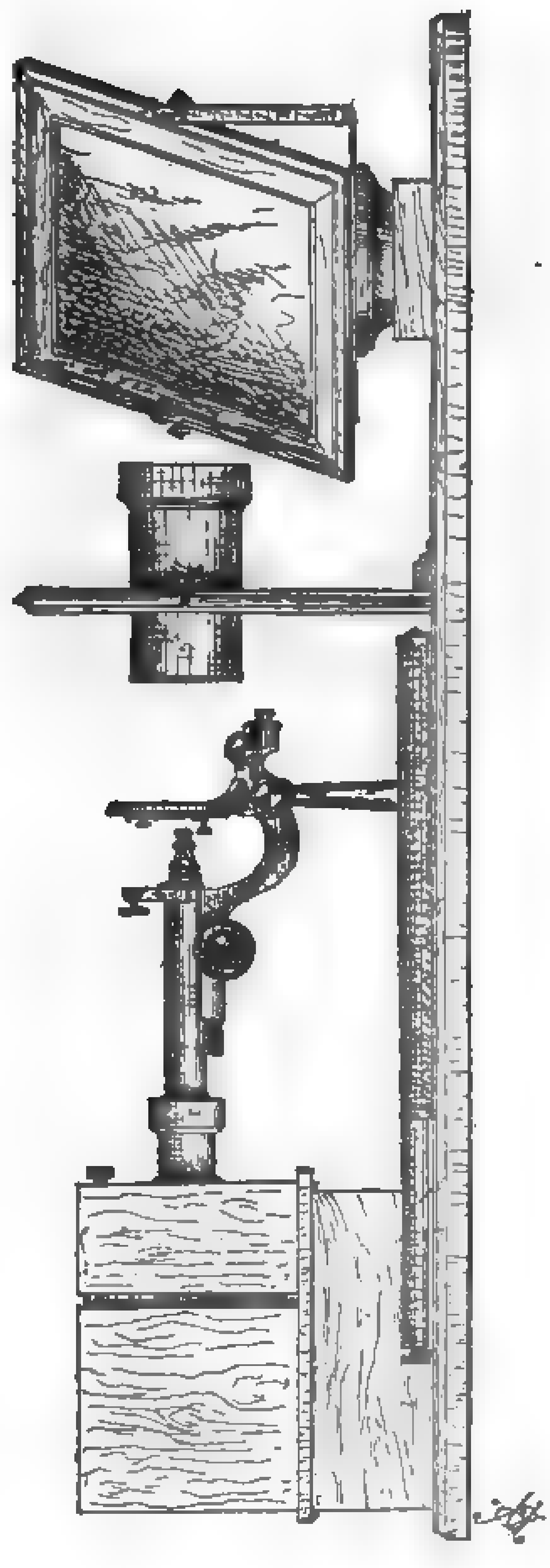
Conditions that were to be met.—1. It was necessary that the patient, the sun and the apparatus with assistants, should all be together, because the blood must be withdrawn from the life stream and transferred to the sensitive plate in the shortest

space of time. 2. The work must be done at different localities so as to have plenty of material to select from and to avoid disturbing elements. From these considerations it is easy to see that the Woodward plan of a dark chamber large enough to hold the operators and assistants could not be adopted, as it could not be carried about.

Figure 1, is a drawing of my best apparatus. Scale $1\frac{5}{16}$ inch to one foot; the base is a black walnut $1\frac{1}{4}$ inch thick board 55 by 11 inches; it is finished with the high polish of the piano maker's art so as to be insusceptible to warping from drying or wetting; running through the middle of it are two brass strips 1 inch wide, $\frac{1}{8}$ thick and $\frac{5}{8}$ inch apart. Beneath the contiguous edges is a deep furrow or groove $\frac{1}{2}$ inch deep and $\frac{11}{16}$ wide. This is not shown in the cut; its object is to have all the apparatus move in one definite median line. At one end is seen the sun mirror 10 by $8\frac{1}{2}$ inches, swung on two arms mounted on a swivel-jointed base; this allows of universal motion. Next is a standard mounted on a base that is attached to the brass groove by a "T" inverted below; the mirror has the same T, the standard rises 15 inches in two grooved posts connected at the top it is $8\frac{1}{4}$ inches wide; a set screw runs through one of the posts; in the groove a quinque-laminated veneer $6\frac{9}{16}$ inches square runs. In it is a hole 4 inches in diameter which admits a collar; in this collar slides an 18-inch Voigtlander photographic objective about 3 inches in diameter; this is adjusted by the set screw in the side of the standard; next on the board comes the Tolles, A microscope stand. The mirror is removed or turned out of the way, the stage is vertical, the $\frac{1}{75}$ inch objective is that on the stand; the eye-piece is removed and the open end of the microscope is pushed within the tube of the camera whose lenses have been removed also. The camera is set up on a box in order to get the requisite height to bring the axis on a line with that of the microscope. The camera moves on the box and the box moves on the base. The three are connected as follows: a groove $\frac{1}{4}$ inch wide and $\frac{1}{8}$ inch deep is cut in the base exactly in the median line and at right angles to the length. This is filled by a piece of ebony $\frac{1}{4}$ inch to $\frac{1}{2}$ inch thick and 4 or more inches long. A brass plate is let into the ebony so that when it is secured by screws it forms the bar of the inverted T before alluded to. When *in situ* this T slides under the base board brass strips. This arrangement is good but don't stand travel by railroad. The same arrangement connects the mirror to the base board.

By the side of the camera is a rod 26 by $\frac{3}{4}$ inches. Two screw eyes are let into the base board just at the ends of the rod. A screw runs through the eye into the right end of the

1.



APPARATUS FOR MICROPHOTOGRAPHY.

rod, and another screw with a milled head goes through the other eye into other end of the rod. The rod is thus secured and rotates by turning the milled head; 17 inches of the rod are covered with sand set like sand paper; in the cut this is covered by a sleeve of enameled cloth as the sand is detached by contact. When used the sleeve is pushed back and a braid or tape is run over the rod and around the milled head of the fine adjustment. A pin secures the ends of the tape when the proper tension is made by drawing them over each other. The delicate focussing is made by the hand of the operator while the eyes are on the ground glass plate of the camera; the tape is not shown in the cut.

Remarks.—It will be noted that the peculiar features of this arrangement which differ from Col. Woodward's plain are, besides the portability; 1, The size of the condenser; 2, The absence of the ammonio-sulphate copper or alum cell.

1. This condenser probably is the largest ever employed in microphotography. The reason of this selection was simply to avoid heat. It is easy to see that if a two-inch condenser is regarded as sufficient that the same amount of light could be obtained with a three-inch, away from the heat focus and thus avoid the effect of focussing the sun's rays on the object and the objective. This practical point has been of great value and explains: 2, The absence of the contrivances to prevent the passage of destructive heat. Dr. Woodward has trouble with these cells, and judging from lately finding him engaged in making a new form of cell for this purpose, it would seem as if this cell was a disturbing element still, though in the hands of the father of modern microphotography.

We have taken a large number of negatives, some of which have received honorable mention abroad: see Journal de Micrographie, Paris, October, 1877, and have used no device to cut off heat; hence we feel justified in saving ourselves the trouble of a, to us, unnecessary appliance. In our opinion this cell has stood in the way of the more general adoption of the reproduction of microscopic objects by photography. We think it is a good rule to use the simplest and fewest things to accomplish a purpose.

For what precedes it is seen how the $\frac{1}{75}$ inch objective was used for photography. The object, for instance, enlarged white blood corpuscles, was displayed on a slide by the sudden drying of a thin film of blood. The corpuscles were found by means of a low power and centered in the middle of the field. Next they were centered by a $\frac{1}{10}$ inch objective, then by the $\frac{1}{75}$. The microscope was then placed as shown in the cut, the eye-piece having been removed. The axis of the condenser, microscope tube, camera and the center of the mirror were

all ranged in one line. By means of the brass furrow in the base board the distances between them were changed without getting out of line. The sunlight, the chemicals, and all else had previously been found in working order by practical tests. Sunlight was thrown by the mirror through the condenser on the object which was placed just beyond the heat focus. We found that the brightest and clearest days, before 3 P. M., were the best. One observer, with his head and the camera covered with a black cloth, noted the projection of the image on the glass-ground plate. Another fingered the fine adjustment, or it was done by the focussing rod. When the image was satisfactory a card board cut off the light by interposition between the condenser and the object. The sensitized plate then replaced the glass plate and exposed, the regular exposure was made by lifting the card board and letting it fall in the course of half a second or more. The time varies and must be learned by trial. Usually it is shown by the action of the chemicals on the exposed sensitive film in the dark room. The processes afterward were those of the ordinary collodion process. It was necessary of course to look over the printing and instruct the printer how much exposure was needed.

In photographing yeast with the $\frac{1}{75}$ inch objective the object was wet and covered with a film of mica. The following facts may not be out of place. It was made by Robert B. Tolles, at Boston, and delivered July 1st, 1873. It was ordered by Dr. Harriman for the sake of working up his demonstration of the presence of nerve fiber in dentine. (American Journal Dental Science, May, 1870, Dental Cosmos, Jan., 1870.) Its angular aperture is 170 degrees; its actual opening on the face, $\frac{1}{64}$ inch. Cover adjustment moves about $\frac{1}{4}$ circle. Works wet or dry. Requires the aid of a powerful condenser. Usually it works best with a B eye-piece as a condenser under the stage, and with the thin edge of a common coal-oil flame shining "direct" into the condenser. It has to be used on a first class stand whose stage is absolutely at a right angle to the tube. With this direct light the field is clear, white and flat. The objective is very sensitive to jars and motions. This troubled us much. We have found in our experience that a cellar in a locality away from avenues of travel is the best place to work in. When an object is in focus with this objective a gentle grasp of the arm that connects the tube with the trunion joint (see cut) is sufficient to move the object out of focus.

The comparative excellence of this objective is not one for much discussion here; some have hastily said that it was of no value, not having used it, while others have looked at it with a sort of awe. In our opinion the question is not settled, though we think something toward it has been done. As far as

our work has been concerned we know that we could not have attained our results with another objective like the $\frac{1}{10}$ for instance, with the ease and facility with which we did with the $\frac{1}{75}$. While we feel sure that the practical clinical results of corroborating our study of consumptive blood can be attained with objectives of $\frac{1}{4}$ inch power—and it would be sad if it were not so—at the same time we are sure that no wrong has been done to any one by pressing the $\frac{1}{75}$ into our service. Moreover, if by our simple arrangement we have been able to transfer images with the highest power objective ever thus used, those who possess the low powers ought to be encouraged to use microphotography with the sunlight without condensing, or with the ordinary mirror, or with the B eye-piece.

2

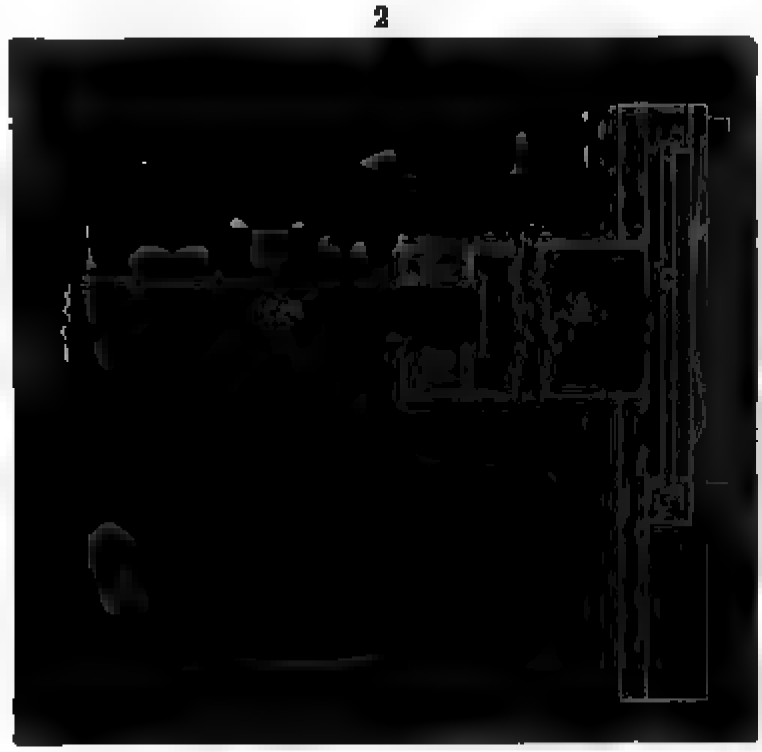


Figure 2 is a section of the writer's device for such work; it may be gotten up at a trifling expense. *a* is the tube of the microscope; *b* is a paper tube 30 by 2 inches. A nicely turned plug of wood adapts the microscope to the paper tube. To save space, the tube is broken off in the cut; a deal 8 by 12 by $\frac{3}{4}$ inches is seen in section, and fitted by a hole to the paper tube *b*. *c* is a section of the ground glass plate and holder, *d* is the clip to hold the plate holders. The artist has omitted the section of the lower cleat. This apparatus is adapted to a quarter plate and a two-inch photograph. An assistant should focus and adjust the light.

With these simple arrangements it would seem that the hope expressed at the outset of this article should begin to be realized.

Tremont Temple, Boston, April, 1879.

Postscript.—The first microphotograph of this objective may be found in the Yale College Library.

ART. XVI.—*Magnetic Strains in Iron;* by A. S. KIMBALL, Professor of Physics in the Worcester Free Institute of Industrial Science.

THE object of this paper is to describe certain experiments made by inducing a magnetic state in bars of soft iron subjected to varying degrees of mechanical stress. As the result, we always have changes either in the form or dimensions of the bar, similar to those produced by the mechanical stress previously applied, and therefore the term *magnetic strain* does not seem inappropriate. Some of the phenomena hereafter to be described have been observed by earlier investigators. These experiments have not been repeated with the expectation of detecting errors in their work, nor of attaining a higher degree of accuracy, but rather, to afford that valuable check which the reproduction of well settled phenomena, with a new disposition of apparatus, affords, both upon the accuracy of the instrument and the skill of the operator.

Effect of Magnetization upon the Tenacity of Iron.—The pieces of iron tested were pulled asunder by a Fairbanks testing machine of 53,000 pounds capacity. The machine consists: 1st, of a large platform scale; 2d, of a powerful screw-straining apparatus, driven by a belt from a shaft having eight changes of speed; the motive power is a Corliss engine which runs with great regularity; 3d, an automatic weighing attachment to the beam, by which it is kept constantly poised as the stress is applied to the test piece.

The delicacy of this adjustment was such, that when the testing proceeded at a suitable rate, the deflection of the beam from the zero point did not indicate a stress on the test piece differing more than two pounds from that shown by the position of the poise on the beam. The scale was "sensitive" to the addition of one ounce when the platform was loaded with 4,000 pounds; and on the removal of the small weight, the beam promptly returned to its normal position. The course of experiment was as follows: Several pieces of the same kind of iron, made as nearly as possible uniform in size, were broken in the machine. The alternate ones, in the order in which they were cut from the bar, were magnetized to saturation by a helix, through which a constant current was passing during the experiment. The heating effects of the helix were slight, and probably without influence. The tabulated results were then compared, and from them the following conclusion was reached: *A soft iron bar has its tenacity increased about nine-tenths of one per cent by magnetizing it to saturation.* The following table gives the results obtained by breaking a series of pieces of

annealed iron wire, very uniformly drawn; approximate diameter, ·1623″. Length between the jaws of the machine, 5″. Time required to break the magnetized pieces, sensibly constant at five and one-quarter minutes; for the unmagnetized pieces slightly less.

TABLE I.

No.	Unmagnetized.	Magnetized.	Difference.
1	1201		9
2		1210	8
3	1202		11
4		1213	11
5	1202		14
6		1216	15
7	1201		9
8		1210	7
9	1203		9
10		1212	9
11	1203		
Mean,	1202	1212	
Minimum,	1201	1210	
Maximum,	1203	1216	
Difference between means,		10 lbs.	
Maximum difference between magnetized pieces,			6 lbs.
" " " unmagnetized "			2 "

Another series of experiments upon telegraph wire gave 8·9 lbs. difference between the means. Seventeen pieces of wire were broken. A series of ten wires, one-quarter inch in diameter, gave an average of unmagnetized pieces, 4532 lbs., of magnetized specimens, 4572 lbs. Difference, 40 lbs.

Some hundreds of pieces were broken with the same results. A magnetized piece always proving stronger than the unmagnetized pieces taken from the coil or bar on either side of it. A few apparent exceptions to this rule showed flaws in the tested pieces on close examination. The average increase of strength in these experiments is very near nine-tenths of one per cent. In every case the strength of the unmagnetized pieces was much more uniform than that of the magnetized. In the Philosophical Transactions of the Royal Society, 1874, p. 571, Sir William Thomson predicts this result as a deduction from Mr. Gore's experiments on Electro Torsion.

Effect of Magnetization upon the Flexure of a soft iron Bar.—Joule's experiments upon the changes in dimensions of an iron bar when magnetized, formed the starting point for this part of the experimental examination in question. He has shown,* 1st. That if an iron rod be compressed longitudinally, it will be slightly elongated upon being made a magnet by a surrounding helix. 2d. That the amount of compression does not affect the magnetic extension so long as the magnetizing force remains the same. 3d. That the same phenomena, in kind and

* Philosophical Magazine, 1847.

amount, occur in a bar which is neither compressed nor stretched. 4th. If the bar be subjected to tension, the elongation, on making it a temporary magnet, is diminished, and as the tensile stress increases the magnetic elongation diminishes through zero and becomes a shortening. 5th. Professor Mayer has shown* that, in the case of an unstrained bar, the first passage of the current elongates the bar more than any subsequent passage of the same current, and that the second, third and all subsequent elongations of the bar by a constant magnetizing force, are equal to each other; also that the shortening of the bar upon breaking the current is constant and equal to the second elongation. These facts, taken in connection with the common theory of flexure, fairly indicate one or two phenomena which will be found to attend the induction of a temporary magnetic state in a bar strained transversely. We see, from what has been said, that the neutral axis, and all the fibers on the concave side of the bar which have been shortened by compression, will be elongated by the action of the magnetizing force, while the fibers of the bar on the convex side, which have been subjected to tensional strain, will either be elongated by a less amount or will be shortened. As the result of this action we may be tolerably sure that the bar will be straightened. It is much safer, however, in this case, to proceed with our investigation experimentally, since neither the theory of magnetic action in iron, nor that of transverse elasticity, can be said to have been fully developed.

The apparatus used in this part of the investigation was simple. A very rigid iron casting, with supports for a micrometer screw, and the ends of the iron rod to be examined upon its upper side, was placed upon the platform of a Fairbanks scale. The iron rod, carefully freed from magnetism and enclosed in its helix, was adjusted upon its supports so that the point of the micrometer screw was just below its middle. The helix was made in two parts for convenience in loading the bar. The middle of the bar supported one corner of a triangular platform, whose sides were four, eight and nine feet. The other corners of this platform were supported upon points. This disposition of apparatus proved very satisfactory. The load upon the bar was easily and accurately determined by the scales, while the stability of the triangular platform permitted the addition or removal of weight without seriously disturbing the adjustment of the bar. The micrometer screw had sixty threads to the inch, and its head was graduated to three hundred parts. The unit of measurement is therefore $\frac{1}{18000}$ of an inch. At first, contacts of the screw with the bar was deter-

* This Journal, August, 1873.

mined by an electric bell, but the probable error of setting the screw being greater than one division of the screw head, a more exact method was sought. The following device was finally hit upon, which gave results which may be trusted to one-half divisions. The iron bar, micrometer screw, and a telephone were put in the circuit of a very weak Leclanche cell. When the screw was turned up to *loose contact* with the bar, the familiar boiling sound of a too sensitive microphone was heard, which ceased the instant *firm contact* was made. The change from the loud boiling sound to silence was abrupt and sharply defined. In the writer's experience this is by far the most reliable method of determining the contact of a screw. In the following experiments, bars of iron ⅝″ square and 24″ long, between the supports, were used. The helix and battery were powerful enough to magnetize it to saturation. The following table gives the results obtained in one series. Complete transcripts of the laboratory notes are given. The deflection of the bar increases with the readings of the screw. Of those readings only the tens and unit figures are retained, as the others may be easily supplied.

Column A, in the table gives the number of the experiment; B, the weight on the bar; C, total deflection after the weight is put on; D, increase of weight; E, increase of deflection due to increase of weight; F, scale readings when the current is off; G, scale readings when the current is on; H, decrease in deflection with the first current after a change in load; I, decrease in deflection with the second, third, etc., currents after a change in load; J=I−H.

TABLE II.

A.	B.	C.	D.	E.	F.	G.	H.	I.	J.	A.	B.	C.	D.	E.	F.	G.	H.	I.	J.
1	Unknown.	Unknown.	Unknown.	Unknown.	87	--	--	--	--	21	22	481	8	173½	72		--	--	--
2					.	83	4			22	"	"	"	"	--	59	--	13	--
3					86		--	--	--	23	"	"	"		72½	-	--	--	--
4					--	83	--	3		24	"	"	"		--	59	.	13½	½
5					86	.	--	--	-	25	30½	652	8½	17	43½	-	--	--	--
6					--	83	--	3	1	26	"	"	"		--	28½	[illegible]	--	--
7	5½	140	5½	140	26	--	-	--	-	27	"	"	"		45	--	-	--	--
8	"	"	"	"	--	19	7	--	--	28	"	"	"		--	28½	--	16½	--
9	"	"	"	"	27	--	--	--	--	29	"	"	"		45	--	--	--	--
10	"	"	"	"	--	19½	--	7½	-	30	"	"	"	"	--	28½	--	16½	1½
11	"	"	"	"	27	--	.	--	--	31	38½	820	8	68	13	--	--	--	--
12	"	"	"	"	--	19	--	8	½	32	"	"	"		--	97½	15½	--	--
13	14	307½	8½	167	95½	--	--	--	--	33	"	"	"	"	15		-	--	--
14	"	"	"	"	--	86	9½	--	-	34	"	"	"	"	--	97½	-	17½	--
15	"	"	"	"	97½		-	--	-	35	"	"	"		14½	--	--	--	--
16	"	"	"	"	--	86	-	11½	.	36	"	"	"		--	97½	--	17	1½
17	"	"	"	"	97½	-	-	--	--	37	46½	991	8½	71	85½	--	--	--	--
18	"	"	"	"	--	86	.	11½	2	38	"	"	"	"	--	66	19½	--	--
19	22	481	8	173½	71	-	-	--	--	39	"	"	"	"	87	--	--	--	--
20	"	"	"	"	-	59	2	-		40	"	"	"		--	66	--	21	1

A.	B.	C	D.	E.	F.	G.	H.	I.	J.	A.	B.	C.	D.	E.	F.	G.	H.	I.	J.
41	55	1160	8½	169	56	--	--	--	--	86	110½	2346	7½	165½	--	13	-	26½	--
42	"	"	"	"	--	37	19	--	--	87	"	"	"	"	39½	--	--	--	--
43	"	"	"	"	58	--	--	--	--	88	"	"	"	"	--	13	--	26½	1
44	"	"	"	"	--	37	--	21	--	89	119	2524½	8¾	178½	18	--	--	--	--
45	"	"	"	"	58½	--	-	--	--	90	"	"	"	"	--	92	26	--	--
46	"	"	"	"	--	37	--	21½	2½	91	"	"	"	"	20	--	--	--	--
47	62½	1326½	7¾	165½	24	--	--	--	--	92	"	"	"	"	--	92½	--	27½	--
48	"	"	"	"	--	4½	19½	--	--	93	"	"	"	"	20	--	--	--	--
49	"	"	"	"	26	--	--	--	--	94	"	"	"	"	--	93½	--	26½	--
50	"	"	"	"	--	4½	--	21½	--	95	"	"	"	"	21	--	--	--	--
51	"	"	"	"	26	--	--	--	--	96	"	"	"	"	--	93½	--	27½	1½
52	"	"	"	"	--	4½	--	21½	2	97	126½	2688½	7½	164	86	--	--	--	--
53	70½	1499½	7¾	174	90	-	-	--	--	98	"	"	"	"	--	59½	25½	--	--
54	"	"	"	"	--	68	22	--	--	99	"	"	"	"	87	--	--	--	--
55	"	"	"	"	92½	--	--	--	--	100	"	"	"	"	--	60	--	27	--
56	"	"	"	"	--	68	--	24½	--	101	"	"	"	"	88	--	--	--	--
57	"	"	"	"	92½	--	--	--	--	102	"	"	"	"	--	61	--	27	1½
58	"	"	"	"	--	68	--	24½	2½	103	134½	2862	8	173½	61½	--	--	--	--
59	78½	1664	7¾	164½	57	--	--	--	--	104	"	"	"	"	--	34½	27	--	--
60	"	"	"	"	--	33½	23½	--	--	105	"	"	"	"	64½	--	--	--	-
61	"	"	"	"	58½	--	--	--	--	106	"	"	"	"	--	36½	--	28	--
62	"	"	"	"	--	34	--	24½	--	107	"	"	"	"	66	--	--	--	--
63	"	"	"	"	58½	-	--	--	--	108	"	"	"	"	--	37	--	28	--
64	"	"	"	"	--	33½	--	25	1½	109	"	"	"	"	65½	--	--	--	--
65	86½	1837	8½	173	21½	--	--	--	--	110	"	"	"	"	--	37½	--	28	1
66	"	"	"	"	--	98	23½	--	--	111	142½	3045	8	183	48½	--	--	--	--
67	"	"	"	"	21½	--	--	--	--	112	"	"	"	"	--	22	26½	--	--
68	"	"	"	"	--	98	--	25½	--	113	"	"	"	"	51½	--	--	--	--
69	"	"	"	"	21½	--	--	--	--	114	"	"	"	"	--	23½	--	28	--
70	"	"	"	"	--	98	--	25½	2	115	"	"	"	"	53½	--	--	--	--
71	94½	2005	7½	168	91½	--	--	--	--	116	"	"	"	"	--	25	--	28½	--
72	"	"	"	"	--	68	23	--	--	117	"	"	"	"	54	--	--	--	-
73	"	"	"	"	--	--	--	--	--	118	"	"	"	"	--	26	--	28	1½
74	"	"	"	"	--	68	--	25½	-	119	160½	3224	7¾	179	33	--	--	--	--
75	"	"	"	"	--	-	--	--	--	120	"	"	"	"	--	6	27	--	--
76	"	"	"	"	--	68		26	2½	121	"	"	"	"	36	--	--	--	--
77	103	2180½	8¾	175½	69½	--	--	--	--	122	"	"	"	"	--	8	--	28	--
78	"	"	"	"	--	44½	25	--	--	123	"	"	"	"	37	--	-	--	--
79	"	"	"	"	72½	--	--	--	--	124	"	"	"	"	--	9	--	28	--
80	"	"	"	"	--	44½	--	28	--	125	"	"	"	"	38	--	--	--	--
81	"	"	"	"	72½	--	--	--	--	126	"	"	"	"	--	10	--	28	1
82	"	"	"	"	--	44½	--	28	3	127	168½	3415	8	191	29	--	--	--	--
83	110½	2346	7½	165½	38	--	-	--	--	128	"	"	"	"	--	2½	26½	.	--
84	"	"	"	"	--	12½	25½	--	--	129	"	"	"	"	31	--	--	--	--
85	"	"	"	"	39½	--	--	--	--	130	"	"	"	"	--	3½	--	27½	1

During the experiments with 94 and 103 pounds, students were passing to their recitation rooms on the same floor with the apparatus, making it quite difficult to determine accurately the contact of the screw. It will be seen that the deflections of the bar shown in C are proportional to the loads, as far as 120 lbs. Above this load the deflections increase more rapidly. Apparent variations from this law may be ascribed to want of accuracy in weighing, as there may be an error of ¼ lb. either way, which corresponds to 6 scale divisions. The experiments

were designed to show changes produced by the passage of the current, and accuracy in weighing was not at first deemed essential. The experiments described, and many others of a similar nature, seem to establish the following conclusions. If a soft iron bar surrounded by a helix and loaded as above be subjected several times to the action of a constant magnetizing current: 1st. The first time the current is made, the deflection of the bar is diminished. 2d. When the current is broken, the weight produces a greater deflection in the bar than before the current was passed. 3d. The second and subsequent currents produce a greater diminution of deflection than the first. 4th. The deflection during the passage of the first and every succeeding current is always the same. The same is true of the deflection after each current, but the deflection previous to the passage of the first current lies between those just specified. 5th. Although the second and subsequent currents have no power for the production of additional permanent magnetic strain as long as the load remains constant, yet, if the load upon the bar be increased, the first current after such a change produces a less effect than those which follow. 6th. If a part of the load be removed from the bar, the first current produces a greater change in deflection than those which follow; in this case, the deflection of the bar is permanently diminished by the first current. This may be illustrated by an extract from a series of experiments made with a diminishing load upon the bar—8 lbs. have just been removed.

A.	F.	G.	H.	I.	A.	F.	G.	H.	I.
101	126½	....	....	....	104	....	105½	....	18
102	...	105½	21	....	105	123½	....	....	....
103	123½	....	....	....	106	....	105½	....	18

The changes in the load upon the bar, heretofore referred to, have been made while the current was broken. 7th. If the load be increased while the current is on, the deflections when the current is broken will be constant, and the deflections with the second and subsequent currents will be greater than those obtained by increasing the load. The changes in deflection the first time the current is broken will be greater than those which follow.

Illustration—8 lbs. have just been added to the load while the current was passing.

A.	F.	G	H.	I.	A.	F.	G.	H.	I.
63	36½	--	--	--	66	---	8½	--	28
64	---	7½	29	--	67	36½	--	--	--
65	36½	--	--	--	68	---	8½	--	28

8th. If the load be diminished while the current is on, the deflections when the current is broken will be constant and the deflections with the second and subsequent currents will

be less than those obtained by decreasing the load. The changes in deflection the first time the current is broken will be less than those which follow.

Illustration—8 lbs. have just been removed while the current was passing.

A.	F.	G.	H.	I.	A.	F.	G.	H.	I.
26	38	---	---	---	29	..	26½	---	11½
27	..	27½	10½	---	30	38	---	---	---
28	38	---	---	---	31	..	26½	---	11½

9th. Changes in deflection produced both by the first and by subsequent currents increase with the load on the bar up to the elastic limit, when they tend to become constant. Below the elastic limit, the law may be approximately expressed by the following formula:

$$(\text{change})^2 = a\ (\text{load} + b).$$

In the series of experiments given in table II, $a=7\cdot2$ and $b=5$, for changes produced by the second currents. 10th. Column J. of the table seems to increase slowly up to the elastic limit, and after passing that point to decrease slowly.

These experiments have been repeated with several grades of iron, and similar results have been obtained in every case; and though many points of the examination have been left incomplete, the writer believes that the conclusions stated above will be found substantially correct.

One point of interest may be noted here. This method of experiment to a certain extent eliminates the effect of temperature changes in iron, since these affect upper and lower fibers of the bar alike, while the phenomena we have been studying are produced by a differential action. How important this is will be seen in a subsequent part of this paper. If we attempt to use the results obtained by Joule and Mayer in explanation of the phenomena exhibited by the transversely strained bar, we find, at the outset, that, though some of them are explained readily, others appear contradictory, and others still need additional data. A series of experiments was next undertaken upon the magnetic elongations of soft iron bars, differing from those of Joule, in using a constant magnetizing current, also in using larger bars and greater tensions;—and from those of Mayer, in using bars subjected to varying degrees of tensile and compressive stress. Many of the results obtained by those accurate experimenters have been reproduced, and others have been obtained, which it is believed are novel and which certainly are interesting. The description of the apparatus employed, and the results obtained, are reserved for another paper.

[Since making the experiments described in this paper, the writer has noticed a reference to an article by M. Guillemin, on

"The straightening of a wire under the influence of a current," Walker's Electric Magazine, 1846. The magazine in question has not been found in any of the libraries consulted; it is therefore a matter of uncertainty how far M. Guillemin has anticipated the results here given.]

ART. XVII.—*The Lœss of the Mississippi Valley, and the Æolian Hypothesis*; by E. W. HILGARD, University of California.

[Read before the National Academy of Sciences, April 16, 1879.]

IN a highly interesting paper read before this body a year ago, and published in the February number of this Journal, Prof. Pumpelly, speaking of the lœss formation, sums up his views on the subject of the origin of these peculiar deposits in the statement that, rejecting his own previously expressed explanation, he is led to "believe with Richthofen that the true lœss, *wherever it occurs*, is a subaërial deposit, formed in a dry central region, and that it owes its structure to the formative influence of a steppe vegetation."

It is not my intention, at this time, to discuss exhaustively the question of the origin of the lœss in general, but rather to formulate some of the more prominent objections lying against the application of the æolian hypothesis to some of the lœss regions with which a long study has made me familiar. The expression "true lœss" leaves some doubt as to how Pumpelly limits the meaning of the word; but assuming that (as seems logically necessary) he uses it in the lithological as well as in its systematic sense, I desire to call attention to some points in connection with the lœss of the Mississippi Valley, which seem to render the æolian hypothesis untenable so far as regards that, and similar deposits elsewhere, which are clearly related to the troughs of large river courses.

The latter fact scarcely needs more than a cursory reference, if only to the circumstance that western geologists have habitually brought the lœss under the general designation of "bluff formation." The lœss of the Rhine, and of the Danube, are familiar to us in the same connection. It can hardly be that Pumpelly is not willing to consider these prototypes as "true lœss."

Now, what are the points in which the typical lœss differs so far from other aqueous deposits, that in spite of this obvious correlation we hesitate to class it as such? Aside from Richthofen's objections based upon the hypsometrical relations of the Chinese deposit (concerning the cogency of which I am unable to judge, not having seen his original publication), there are two principal ones, viz:

1. Absence of stratification.
2. Absence of fossils of aqueous origin.

As to the absence of stratification, it is admitted on all hands that even the most typical lœss, everywhere, often shows "bedding planes;" which manifest themselves more or less by a tendency to terraces, or lines of more rapid erosion on the otherwise vertical walls. This occurs more rarely in the central regions of the lœss masses; but on the peripheric ones it is not only quite frequent, but amounts in some cases to the most unmistakable appearance of aqueous stratification. Such is the case in the lœss bluffs of the Ohio in Southern Indiana, where my attention was called to it by Dr. David Dale Owen. It occurs also, though not quite so strikingly defined, along the edge of the "American Bottom" in Illinois, opposite and above St. Louis. Generally speaking, indications of stratification in the lœss are more frequent as we advance from the axial and lower regions of a river valley toward the sides and heads.

In the Sixth Annual Report of the Geological Survey of Minnesota, Prof. N. H. Winchell pointedly refers to the obvious transition of the lœss deposits into those of the newer Glacial period. Similarly, as stated in my Mississippi report (pp. 195, 298) and in a memoir on the Geology of Lower Louisiana (Smithson. Contr., No. 248, pp. 4 and 5), the lœss of the Lower Mississippi passes laterally, and by imperceptible degrees, into a clayey loam undistinguishable, in its final landward form, from that which forms the general subsoil of the Southwestern States; and almost precisely the same change occurs to the southward, in Louisiana, the representative deposits appearing, in that case, quite distinctly stratified into beds of materials more or less differentiated from the typical lœss.

Now, if the lœss of the Mississippi trough is of aqueous origin at the heads, the sides, and the lower end of that trough, and is, moreover, covered, normally, by a deposit whose pebbles and sand streaks can leave no possible doubt of a general shallow submergence immediately following, and terminating, the lœss period; it is not easy to see how the central portion of the deposit can have been in a subaërial condition, as required by Richthofen's hypothesis.

Is, then, the deposit of the Mississippi trough not a "true lœss?"—I have compared it carefully, in every respect, with the descriptions given of the characteristics of the lœss elsewhere, geologically, palæontologically, structurally and chemically; and I despair of finding any material differences, or such as may not be found, as variations, in any lœss district. It is true that the drainage of the Mississippi "cane hills" has not, as a rule, cut cañons with vertical walls, but narrow V-shaped

valleys between sharp-backed ridges.* But wherever vertical cuts have been made, they stand like stone walls, unaffected by the weather; and even the subterranean villages of the Chinese lœss had their counterpart at the siege of Vicksburg. Where the deposit abuts against the older formations, we have a great abundance of land snails, as well as pebbles derived from the older drift, which usually appear in "strings" sloping away from the land. The "lœss-puppets," too, are there, varying in size, as the results of a mechanical analysis show, from the tenth of a millimeter to that of lumps and spindle-shaped masses weighing as much as ten pounds. The intimate vertical tubular structure I have not had occasion to verify; but long tubular concretions, apparently the casts of rootlets, occur frequently, not only in the older portions, but as a modern formation around decaying rootlets; which cannot be otherwise, since all the streams of the region are depositing calcareous tufa.

But if it must be admitted that the lœss of the Lower Mississippi is a true, typical lœss, exhibiting all the lithological and structural characteristics by which that deposit is recognized elsewhere; and that hypsometrical and stratigraphical data compel us to assume that it has here been formed under water: then the mainstay of the æolian hypothesis falls at once, for what has happened here can have happened elsewhere. Nor should it be forgotten that, if the lœss does not exhibit the usual features by which we are accustomed to recognize aqueous deposition, it is, on the other hand, equally devoid of the evidences of wind-drift structure, which ought to be very obvious at least in the windward portion of the lœss regions. On the contrary, it seems that all observers testify to its dead uniformity over the entire areas: so that with the exception of such differences as would be expected to occur from the rolling down of debris, and the local action of streams, there is no constant mechanical or chemical difference between the windward and the leeward regions. At least no such differences are reported in the United States; nor are they mentioned in the *resumés* of Richthofen's views that have been published.

As to the absence of almost all but terrestrial fossils, save locally where the material generally is more clayey, I cannot help suspecting some connection between this fact and the solution and re-deposition of carbonate of lime, so constantly and rapidly going on in these deposits. The adherents of the æolian hypothesis find no difficulty in accounting for the absence of every vestige of the vegetation which they consider as a more or less essential agent of its formation. According to them, this vegetation has left no mark but the tubes originally coat-

* See Rep. on the Geology and Agriculture of Mississippi, 1860, pp. 194, 313, ff.

the rootlets. Now it is not easy to see, how under such ımstances any shell consisting of calcic carbonate can ain undissolved. I here recall to mind my observations on deposits of the later (Grand Gulf) Tertiary of the Southern States; where in a deposit evidently formed on the es of the Gulf, consisting of fine-grained sandstones, clayes, and in some cases silts scarcely distinguishable from of the lœss period, we have such an absolute dearth of ls that my most elaborate search in hundreds of localities, an area nearly a hundred miles in width by two hundred fifty in length, covered with rocks admirably adapted to preservation of fossils and of an aggregate thickness of about feet, has nevertheless failed to give any more definite clue to fauna and flora than a few unrecognizable leaves, and a ly identifiable fragment of a turtle shell. The latter, how-, was found in a stratum of clay containing an abundance alcic carbonate in the shape of veins and irregular concres, which in one locality at least showed plainly the general ines of molluscan shells. The same features are repeated he overlying strata of the "Port Hudson Group," which ıediately underlie the lœss and are intimately connected ı it. Here also there is an inexplicable scarcity of fossils; calcareous concretions prevail everywhere, and fortunately, ome of the more clayey portions the maceration has only ially destroyed the forms of the shells; so that after tracing ratum filled with concretions for miles, one will occasionsee these nodules taking shape, and finally, for a few feet, ibit a very copious fauna, which, farther on, is again repreed only by calcareous concretions.*

ases in point are, of course, far from rare, and have prob- come under the observation of most geologists in the ; but I think they have too often remained without men-, in the usual eagerness to find and describe well-character- fossils. In my view, the wonder in the case of the lœss is, that there should be so few vestiges of animal and plant but rather that any such should have escaped disintegra-, under the oxidizing and dissolving processes that have ı going on so long in so porous a material.

ut why the exceptions in favor of the terrestrial animals? eems to me that their localities of occurrence give a pos- clue to the distinction. The destructive processes are ntially dependent upon the presence and percolation of r; and this should be least in the marginal portion, where matter of fact most of the terrestrial fossils are found. ether in addition, there is a difference as to destructibility

ee my Memoir on the Geology of Lower Louisiana, and the Rock-salt De- of Petite Anse; Smithson. Contr., No. 248, 1872.

of land- as compared with fresh-water shells, may be a question deserving investigation. That the phosphatic bones should not have dissolved as easily as the mere carbonate shells, is readily intelligible; and as regards their mode of occurrence, I remark that in the lœss of the Lower Mississippi they are always very much scattered, many bones belonging to the same individual being rarely found together, but seeming to have drifted widely apart. It is not easy to see how the cumbrous bones of the Mammoth could have been widely separated in a subaërial deposit.

But I think that apart from its geological and other relations, there is intrinsic evidence in the nature of the material, contradictory of its æolian origin. In a paper lately published, I have drawn attention to a general distinctive feature of fine detrital aqueous deposits, viz: the necessary state of "flocculation" in which they are deposited, so long as the water is not absolutely quiescent. Excepting only under conditions of such moisture as would preclude the possibility of conceiving the wind as an adequate cause, dust deposits cannot be in a flocculated condition, but in the very nature of the case must consist of single grains closely packed. It is true that this axiom does not seem to accord with our every-day experience; for the dust of our roads, as well as that which we take off our furniture once a week, lies very loosely and is evidently not of a "single-grain" structure. But the organic "fluff," and hygroscopic and glutinous impurities causing this looseness of texture, could form no important part of the material carried by the supposed secular wind-storms of the lœss era. Now as the lœss is naturally one of the most porous and pervious of deposits, so as hardly to require tillage; and since moreover, it is shown by mechanical analysis to consist largely of minute spheroidal concretions—in other words, of floccules permanently fixed by the calcareous incrustation, precisely as should be the case if it *were* an aqueous deposit; while if a wind-deposit we should expect it to be cemented bodily into a continuous, rock-like mass: I submit that this structural peculiarity renders the aqueous origin of the lœss extremely probable. It may be possible to corroborate this argument, however, by direct experiment, in cases where the formation of calcareous concretions has not so far fixed the floccules as to render the production of slaty cleavage by pressure impracticable; and on the other hand, I intend to ascertain by direct trial, in what manner the lœss material will be deposited by an artificial wind, after freeing it from the calcareous cement by digestion in weak acid; and also, what will be the effect of pressure upon the material so treated, in the tamped condition on the one hand, and in the flocculated on the other.

Again, I am unable to see how the æolian hypothesis can account for the chemical peculiarities of the lœss. It seems to me to be very far from having the composition of the average rock dust of the earth's surface; nor does it present the chemical condition in which we would expect to find such dust. What has become of the feldspars, or of their products of decomposition? Admit that their dust would, by this time, all have been kaolinized, how can an average of two and a half or three per cent of alumina, shown by analysis, account for it? The previous decomposition products of the rocks of the great Western Plateau, as shown us by the Tertiary deposits, tell a very different tale, in the large prevalence of clayey strata; and it is from these very strata, moreover, that the largest part of the lœss material must, in one way or another, have been derived. It is easy to understand that the clay could be carried to the Gulf in suspension in *water;* but where did it finally lodge on the æolian hypothesis? If it be objected that, as stated by Prof. Brewer, "some of the lœss material is so fine as to remain in suspension for a year," I reply that although it will not stay so for one minute where any considerable amount of lime or other neutral salt is present in solution; yet, should the water be alkaline, the clay will remain suspended indefinitely. As there is a superabundance of sources of carbonated alkalies in the region in question, no objection can be raised to the aqueous origin of the lœss, on the score of its containing too much lime to permit the clay to escape to seaward. But I do consider that large average percentage of calcic carbonate, which so uniformly characterizes the lœss everywhere, as another serious objection to its æolian origin; it being out of all proportion to the alumina, not only on the score of general averages, but also on that of the slow, and almost exclusively aqueous mode of disintegration of limestone proper. If on the other hand, the lime was chiefly carried in solution, and from this assimilated by testacea whose shells were afterwards mostly destroyed by maceration, its presence is readily accounted for.

I do not, of course, pretend that the considerations I have here presented should be accepted as conclusive against the æolian hypothesis. But it seems to me that the points mooted require a fuller consideration than they have heretofore, so far as I am aware, received at the hands of the advocates of that hypothesis; and that they suggest a line of investigation not adequately pursued as yet. We are not yet cognizant of the precise nature of the varying conditions under which thick aqueous deposits apparently devoid of stratification may be formed; as they are even in flowing water, and may be seen in the deposits of the Mississippi River after any great overflow; as also in the stratified drift of the Southern States, where

the "flow and plunge" structure is the rule. If it can be said (as I do *not* think it can) that no deposits similar to the loess are now in process of formation by lakes: neither have we at this time, any example of the accumulation of such deposits through the agency invoked by Richthofen, on any considerable scale; although the postulated conditions exist in not a few regions. All dunes and drifted desert sands show wind-drift structure, as a necessary consequence of the varying velocity of the wind; and it seems to me that even in the presence of the supposed steppe vegetation, a condition of things under which that structure should nowhere appear, or should have been destroyed afterwards, is much more difficult to imagine than that, under the anomalous conditions of the "Champlain" period of depression, such conditions of aqueous deposition as we now find only exceptionally, should have prevailed more generally and for a longer time; a time, however, immeasurably shorter than that to which we must stretch our imagination for the formation of a thousand feet of dust deposit, brought by a wind so uniform in its direction and velocity as to leave no trace of the proverbial variability of that agent. And when we find ourselves driven to the supposition that this extraordinary wind did, moreover, drop its uniformly fine dust into the trough of the Lower Mississippi, leaving all the adjoining upland without a vestige for hundreds of miles on either side: the sum-total of anomalous conditions required to sustain the æolian hypothesis partakes strongly of the marvellous.

ART. XVIII.—*On a method of swinging Pendulums for the determination of Gravity, proposed by M. Faye;* by C. S. PEIRCE.

[Read before the National Academy Academy of Sciences, April 17th, 1879, with authority of the Superintendent of the U. S. Coast and Geodetic Survey.]

AT the Stuttgart, 1878, meeting of the International Geodetic Association, M. Faye suggested a method of avoiding the flexure of a pendulum-support which promises important advantages. The proposal was that two similar pendulums should be oscillated on the same support with equal amplitudes and opposite phases. If the pendulums could be made precisely alike, the amplitudes precisely equal, and the phases precisely opposite, it is obvious that the support would be continually solicited by two equal and opposite forces and would undergo no horizontal flexure, except from the distortion of the parts between the two edges. But since none of these three elements can be made equal, it is necessary to inquire what would be the effect of such slight imperfections in their equalization as would have to be expected in practice.

I had the advantage many years ago of learning the main characteristics of the mutual influence of pendulums from Professor Benjamin Peirce. As my father's studies of the subject were never, I believe, written out, I am unable to say definitely what I derive from that source. But the truth is the little knowledge I have of mathematics was learned from him, and from him I got a clear idea of the nature of this particular problem; so that acknowledgments of detail, even if I were able to make them, would be quite inadequate.

In M. Faye's proposed experiment, four finite forces would be in operation, namely: the weights of the two pendulums, the elastic force tending to restore the two knife-edge supports to their position of equilibrium when they are both displaced together, and the elastic force tending to restore them when their relative positions are displaced. The system has, also, four degrees of freedom corresponding to motions against each of the four finite forces. Accordingly there will be four differential equations of motion. By neglecting the terms of the second order, these equations are made linear, and by the general theory of such equations, they indicate that each of the four motions of the system (viz., those of the pendulums and of the two knife-edges) is compounded of four simple harmonic motions. Two of these will have periods nearly equal to those of the pendulums; the other two will be mere tremors having periods nearly those of the natural elastic oscillations of the supports. These tremors will be so small that they may be neglected. In fact, if we simply suppose that the knife-edges are constantly in equilibrium under the various forces which solicit them (which is simply to neglect their living forces under their very small velocities) the tremors disappear, to the great simplification of the formulæ.

Putting, then, φ_1 and φ_2 for the momentary angles of displacement of the two pendulums, s_1 and s_2 for the momentary horizontal displacements of the two knife-edges, l_1 and l_2 for the lengths of the two equivalent simple pendulums (on an absolutely rigid support), g for the acceleration of gravity, and t for the time, we have

$$l_1 \frac{d^2\varphi_1}{dt^2} + \frac{d^2 s_1}{dt^2} = -g\varphi_1$$

$$l_2 \frac{d^2\varphi_2}{dt^2} + \frac{d^2 s_2}{dt^2} = -g\,\varphi_2.$$

These equations are exactly like what we have in the case of a single pendulum on a flexible support; and I have shown their correctness in my paper on that subject.

There would be no difficulty in making the two pendulums so nearly alike that they might be regarded as entirely so in their actions on the stand, the whole amount of which is small.

We may also consider the parts of the stand on which the two knives rest as equally elastic. We may therefore take $\frac{1}{2}(s_1+s\ )$ as proportional to $\frac{1}{2}(\varphi_1+\varphi_2)$, and $\frac{1}{2}(s_1-s_2)$ as proportional to $\frac{1}{2}(\varphi_1-\varphi_2)$. Denoting, then, by x and y two constants whose values will be easily determinable by experiments we have

$$s_1+s_2=(x+y)\ (\varphi_1+\varphi_2)$$
$$s_1-s_2=(x-y)\ (\varphi_1-\varphi_2)\ ;$$

or

$$s_1=x\varphi_1+y\varphi_2$$
$$s_2=x\varphi_2+y\varphi_1.$$

Substituting these values of s_1 and s_2 in the differential equations, and also writing $l+\delta l$ for l_1 and $l-\delta l$ for l_2, they become

$$(l+x+\delta l)\frac{d^2\varphi_1}{dt^2}+y\frac{d^2\varphi_2}{dt^2}=-g\,\varphi_1$$

$$(l+x-\delta l)\frac{d^2\varphi_2}{dt^2}+y\frac{d^2\varphi_1}{dt^2}=-g\varphi_2.$$

The solution of these equations is (A, B, t_1, and t_2 being the arbitrary constants)

$$\phi_1=\mathrm{A}\cos\left\{\sqrt{\frac{g}{l+x-\sqrt{(\delta l)^2+y^2}}}\cdot(t-t_1)\right\}+\mathrm{B}\cos\left\{\sqrt{\frac{g}{l+x+\sqrt{(\delta l)^2+y^2}}}\cdot(t-t_2)\right\}$$

$$\phi_2=-\mathrm{A}\left(\frac{\delta l}{y}+\sqrt{1+\left(\frac{\delta l}{y}\right)^2}\right)\cos\left\{\sqrt{\frac{g}{l+x-\sqrt{(\delta l)^2+y^2}}}\cdot(t-t_1)\right\}$$
$$-\mathrm{B}\left(\frac{\delta l}{y}-\sqrt{1+\left(\frac{\delta l}{y}\right)^2}\right)\cos\left\{\sqrt{\frac{g}{l+x+\sqrt{(\delta l)^2+y^2}}}\cdot(t-t_2)\right\}$$

The condition that the pendulums are started by drawing them away from their positions of equilibrium and then letting them escape nearly at the same instant makes t_1 and t_2 nearly equal. We may reckon the time from the mean instant of starting. Then at that instant we have very nearly

$$\varphi_1=\mathrm{A}+\mathrm{B}$$
$$\varphi_2=-\mathrm{A}\left(\frac{\delta l}{y}+\sqrt{1+\left(\frac{\delta l}{y}\right)^2}\right)-\mathrm{B}\left(\frac{\delta l}{y}-\sqrt{1+\left(\frac{\delta l}{y}\right)^2}\right);$$

or if we write z for $\frac{\delta l}{y}$,

$$\varphi_2=-\mathrm{A}\ (z+\sqrt{1+z^2})-\mathrm{B}\ (z-\sqrt{1+z^2}).$$

And since the amplitudes are nearly equal and the phases nearly opposite,

$$\varphi_1=-\varphi_2,$$

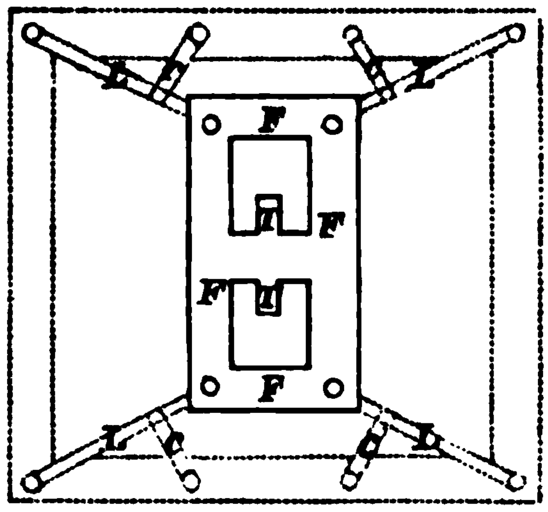
or $\mathrm{A}+\mathrm{B}=$(nearly) $\mathrm{A}\ (z+\sqrt{1+z^2})+\mathrm{B}\ (z-\sqrt{1+z^2})$

This gives

$$\frac{\mathrm{B}}{\mathrm{A}}=\text{(nearly)}\ \frac{\sqrt{1+z^2}-1+z}{\sqrt{1+z^2}+1-z}.$$

ıere would be no insuperable difficulty in making the penms so near alike that δl should be less than y, even if the · quantity were smaller than it would be likely to be. it will be seen presently that care must be taken in the ;ruction not to make y too small.

1.



shall have then $\delta l < y$ or $z < 1$; ıce $B < A$. Thus the amplitudes ıe first terms in the expressions ›oth φ_1 and φ_2 are greater than : of the second terms, while the d of the first terms is shorter than ›f the second terms. From this it ›e shown to follow that the whole ations of the two pendulums have ıame period, which is that of the onic motions represented by the first terms of their values. ı, in the figure, the abscissas representing the time, we a wave of short period and large amplitude placed in com· on with a wave of long period and small amplitude.

ıe phase of the short wave advances on the long one and over and over it. In each complete cycle of the curve ·senting the short wave, beginning and ending at $y=0$, it cut the other curve twice unless the latter has mean time ed the axis of abscissas once and not twice. When this hap· there will be three intersections or only one, according to lirection of the crossing. Hence when the short curve has nced over any even number of crossings by the long one ıe axis of abscissas, the mean number of intersections per : of the short curve will be exactly two. Now let the short ǝ represent the first term in the expressions for φ_1 or φ_2 .et the long curve represent the second term *with its sign ʒed;* then, the intersections will represent passages of the ulum over the vertical, and it will be seen that there are for each complete period of the quicker harmonic com· nt of the motion.

ıe mean period, then, of the oscillation of either pendulum be

$$T = \pi \sqrt{\frac{l+x-\sqrt{(\delta l)^2+y^2}}{g}}.$$

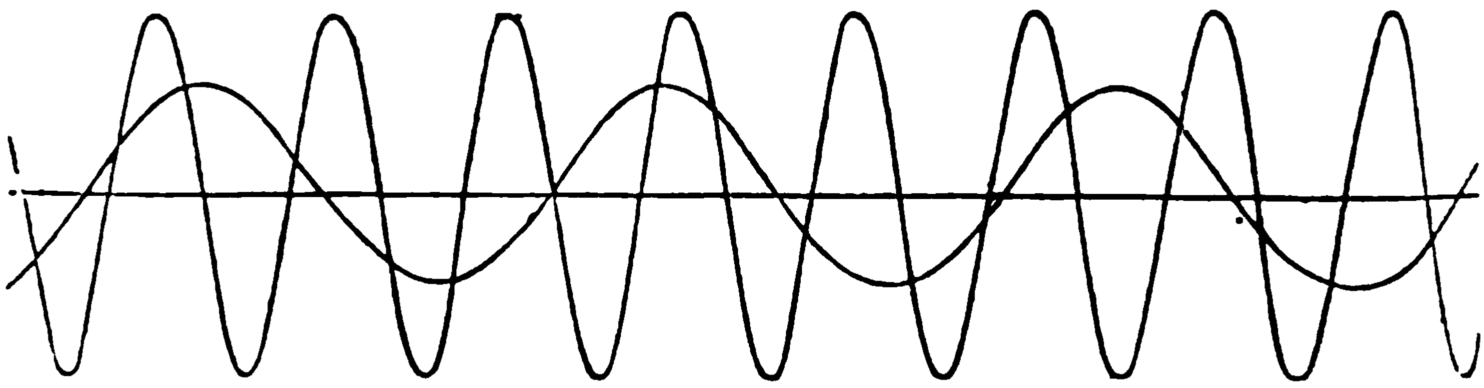
ʳ let us suppose that δl is so small that $\frac{1}{2}\frac{(\delta l)^2}{ly}$ may be neg· :d, being less than one millionth. This would happen, for ınce, if l were one meter, y a half a millimeter (so that the d would be somewhat less stiff than the Repsold tripod), δl were one twenty-fifth of a millimeter, so that the dif· ıce between the natural times of oscillation of the two pen·

dulums was not over four seconds a day, a perfectly attainable adjustment. Then the period would reduce to

$$T = \pi\sqrt{\frac{l+x-y}{g}}.$$

The terms $x-y$ here indicate that the apparatus would still be subject to a correction for flexure: but it would be only for the relative flexure due to the distortion of the support between the two knife-edges. This could of course be made very small. It would still have to be measured: but it would be measured once for all, since it would be the same at all stations. At present, the measurement of the flexure at each station, involving as it does the erection of a separate pier, threatens to be one of the most troublesome and expensive parts of the whole work of determining gravity. This would be entirely obviated by M. Faye's plan, except that the small differential flexibility would have to be determined once for all. The proper way to make the stand so as to bind the two knives to their relative position as firmly as possible while allowing a moderately large flexibility to the whole stand, so that the two pendulums could freely influence one another, would easily be found out.

2.



The accompanying figure, for instance, represents one such arrangement as viewed from above. T, T, are tongues upon which the pendulums would rest. These would be cast in one piece with the heavy frame F, F, F, F. This frame would rest on four legs L, L, L, L, which would spread at the bottom in the direction of the motion of the pendulum. At the bottom they would be bolted into another heavy frame. The cross braces C, C, C, C, would prevent twisting.

The average period of oscillation of either pendulum, after correction for flexure, would be that belonging to a simple pendulum having the length l, the mean of the lengths of the two simple pendulums whose natural periods of oscillation would be the same as those of the given pendulums. But although this would be the average time of oscillation of either pendulum, yet neither pendulum would have all its oscillations of the same duration. It is, therefore, necessary to inquire what error might arise owing to the observations not extending over any exact number of cycles of motion, so that the mean

he observed periods would not be the same as the mean of periods of a cycle.

he quickest oscillation of either pendulum would occur n the phases of the component harmonic motions were cident, the slowest when these phases were opposed. The od of the slow harmonic component motion would be

$$\pi\sqrt{\frac{l+x+y}{g}}$$

ıe mean of the periods of the two given pendulums oscilıg on the given stand with coincident phases, so as to be ted by the flexibility of the whole stand but not by its lity to distortion. Suppose, then, that in the course of experiment an instant comes at which the pendulums are ical at once. Let us reckon the time from this instant, put

$$\mathrm{I}=\frac{\mathrm{A}}{\mathrm{B}}\cdot\frac{\sqrt{1+z^2}-1+z}{\sqrt{1+z^2}-1-z},$$

ıat I is nearly unity. Then using the abbreviations

$$\sin_1=\sin\left\{\sqrt{\frac{g}{l+x-\sqrt{(\delta l)^2+y^2}}}\cdot t\right\}$$

$$\sin_2=\sin\left\{\sqrt{\frac{g}{l+x+\sqrt{(\delta l)^2+y^2}}}\cdot t\right\}$$

ıave

$$\mathrm{C}\,\varphi_1=(\sqrt{1+z^2}+1-z)\sin_1\pm\mathrm{I}\,(\sqrt{1+z^2}-1+z)\sin_2$$

$$\mathrm{C}\,\varphi_2=(-\sqrt{1+z^2}-1-z)\sin_1\pm\mathrm{I}\,(-\sqrt{1+z^2}+1+z)\sin_2,$$

re the double sign distinguishes between coincidence and osition of the phases of the harmonic constituents at the of t.

hen since the value of z is between 0 and unity, the values nese four coefficients lie

$\sqrt{1+z^2}+1-z$	between	2 and	1·414
$\sqrt{1+z^2}-1+z$		0	1·414
$-\sqrt{1+z^2}-1-z$		−2	−3·414
$-\sqrt{1+z^2}+1+z$		0	0·586

follows that for one pendulum the phases of the harmonic stituents are coincident at the moment when they are for the r in exact opposition. Hence, one pendulum is making its est oscillation at the moment when the other is making its kest, and *vice versa*. Then from the symmetrical character armonic motion it follows that if observations were taken of

both pendulums during any interval of time, then the mean of the average periods of the two during that interval, would give the mean period of either through a complete cycle of motion. A better method of observing, however, would be to set up a lens between the two pendulums, so as to bring the plane of oscillation of the one into focus on the plane of oscillation of the other. Then, by means of a reading telescope set up at a little distance, the oscillation at which both crossed on the vertical could be noted with some accuracy. It would then only be necessary to determine the mean period of oscillation of either from one such event to another. As the difference between the longest and shortest periods of oscillation would only amount to a few ten-thousandths of a second, it would not be necessary to be very exact in the time of beginning or ending the experiment. The number of oscillations between one coincidence at the vertical and another would afford a very accurate determination of y. For suppose n to be that number. Then

$$n\sqrt{\frac{l+x-y}{g}}=(n-1)\sqrt{\frac{l+x+y}{g}},$$

whence

$$l+x=\left(n-\frac{n-1}{2n-1}\right)y.$$

But as n is large (several thousand) we may take $\frac{n-1}{2n-1}=\frac{1}{2}$, and x as equal to y.

This gives $y=\frac{l}{n-\frac{3}{2}}$.

Then $x-y$ having been determined, we ascertain the value of x also.

The greatest departure of the oscillations of the two pendulums from complete opposition of phase would occur when the phases of the harmonic components differed by a quadrant. In this case, the pendulums would cross at an angle equal to CI$\frac{\delta l}{y}$ from the vertical. The difference in the time of their passage over the vertical could only amount to a minute fraction of a second.

If the pendulums should not be nearly enough adjusted to the same natural period, or if the stand should be too stiff, so that δl were greater than y, the slower harmonic component would have a greater amplitude than the quicker one. In this case, the pendulums would pass over all differences of phase, and whether the mean period of oscillation were that of the faster or of the slower component might depend upon the initial phases, or, if δl were still larger relatively to y it might be the same as if the pendulums were oscillating with coinci-

dent phases. Care would have to be taken to avoid such a state of things.

On the whole, it appears that the suggestion of M. Faye, though it was thrown out on the spur of the moment, and was not received with very warm approval on every hand, is as sound as it is brilliant, and offers some peculiar advantages over the existing method of swinging pendulums.

Feb. 17, 1879.

ART. XIX.—*Geology of Virginia: Continuation of Section across the Appalachian Chain;* by J. L. CAMPBELL, Washington and Lee University.

IN the number of this Journal for July last, a general outline of the geology of the Great Valley of Virginia was given, and illustrated by a section embracing the several epochs represented in the valley proper, and in the two mountain ranges forming its boundaries on the southeast and northwest. That section may be regarded as a typical representation of the several varieties of rock that come to the surface for many miles on both sides of it.

In the present paper I propose to give what may be regarded, in part at least, as an extension of the same section—the results of observations made in the same general direction, but not exactly on the same line. Moving the line of section about eight miles toward the northeast of my former route, I shall fall back and begin again within the limits of the Great Valley; the reasons for which are, first, to renew the connection with the lower Silurian limestones, that will again make their appearance in an interesting anticlinal valley at the other end of the section; and secondly, that we may pass through or near a considerable number of points of no little interest, and easily accessible to the scientific traveler or the student of geology.

What is here presented is, in its main features, the result of a survey made several years ago, in conjunction with the Hon. Wm. H. Ruffner, LL.D., the present Superintendent of Public Instruction in Virginia, and who is a gentleman of no mean attainments in geological science. Some important details that are introduced, as well as some of the generalizations, are the fruits of subsequent observations made by myself in review of our original work. The main conclusions, however, stand as originally agreed upon.

It would hardly be proper to call this an "ideal" section, since some of the most interesting portions of it represent *real*

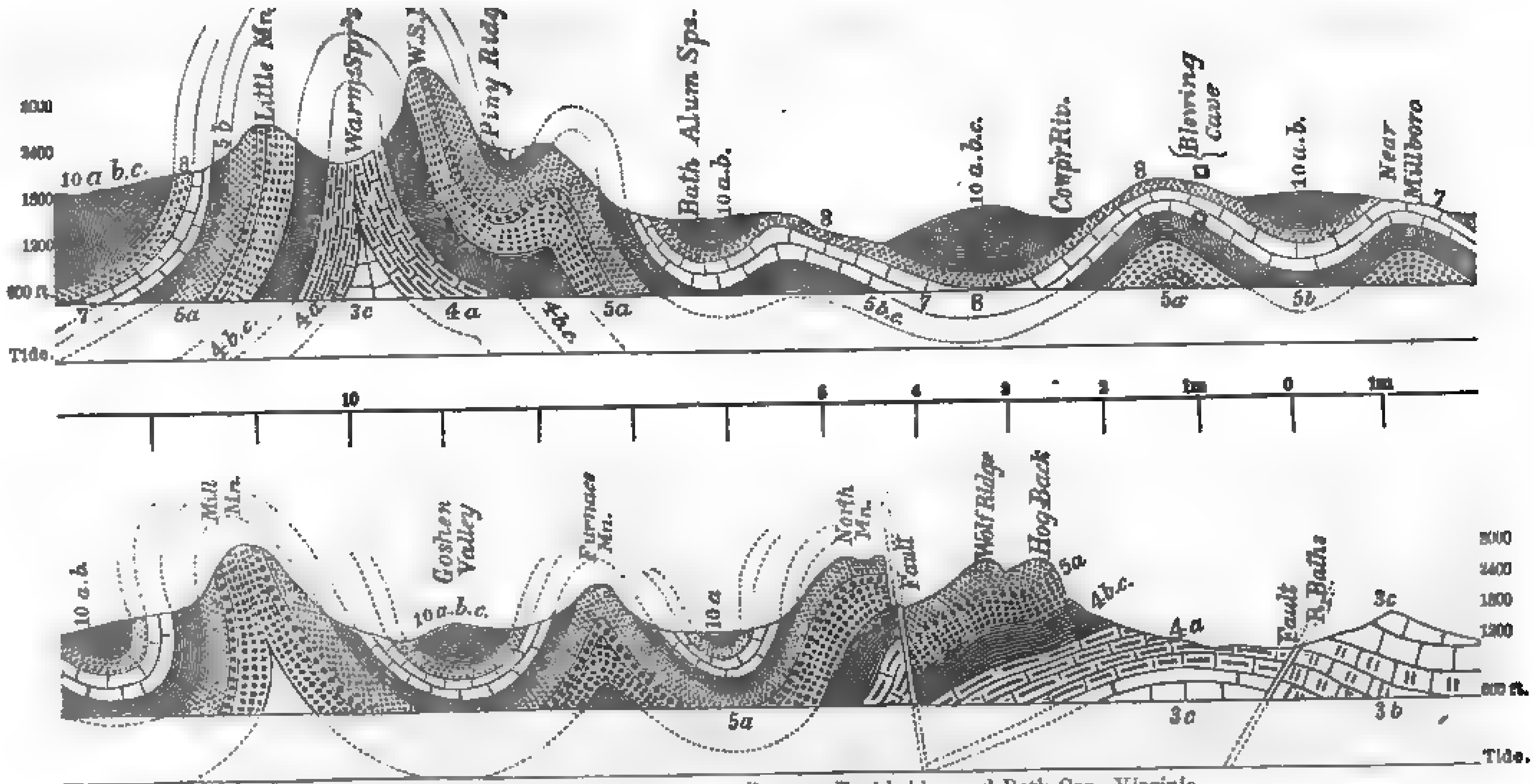
sections that nature has opened up to our view on a grand scale —where the geologist may revel, or the student of science find interesting and profitable employment for many days together. It passes through or near several mountain gorges of considerable depth and extent, as well as many points of minor interest, where mountain streams have cut their channels through the lower hills and thus exposed the various formations along its lines.

On my former section the series of Professor Rogers was given with sub-divisions; and a table appended to present a comparison of these with the corresponding periods and epochs given in Professor Dana's Manual, so far as the equivalents have been definitely determined in this part of the Appalachian chain. On the section accompanying the present paper, the numbers and letters refer to Professor Dana's system.

Beginning, then, with the southeastern extremity, near the Rockbridge Baths, we find a natural section cut by the North River through a part of 3 *a* and the whole of 3 *b* and *c*, etc. (Calciferous, Quebec and Chazy=No. II Rogers). In the immediate vicinity of the Baths these formations are very much obscured by the Quaternary deposits of drift from the mountains above, but they may be studied conveniently at points a mile lower down on the river cliffs, or on the neighboring hills a little remote from the river, on the southwest side, where the section passes. For a description of the rocks of this period, the reader is referred to the number for July.

The line of fault presented on the former section continues, with a single interruption, some distance beyond the present section, crossing the river a short distance above the Baths (N.W.)—the older (3) being still thrust upward over the edge of the newer (4 *a*.) This junction of the displaced strata can be seen indistinctly along the river banks at low water, but may be more distinctly traced in the hills southwest of the river, and on Hays' creek northeastward.

This fault has doubtless much to do with determining the temperature of these thermal Baths, the waters of which have a temperature of 72° F., and are kept in gentle but constant agitation by escaping bubbles of gas, consisting largely of nitrogen and carbonic acid. The remedial virtues of the Baths have been long recognized. As we pass up the river in a northwesterly direction we soon find the Trenton limestones forming the bottom of the river-bed where the strike of the strata can be distinctly seen crossing the stream nearly at right angles. The same rocks also crop out on the neighboring hills, which generally have a rounded shape and are strewed with quantities of local drift from the adjacent mountain gorges. There are no cliffs here; for these argillaceous lime-



SECTION OF SILURIAN AND DEVONIAN ROCKS—Rockbridge and Bath Cos., Virginia.

stones and overlying shales were too fragile to withstand the denuding force of the vast floods of water and masses of sandstone bowlders that have, at some past period of time, come down with violence from the neighboring mountains and the valleys beyond. Both the lithological and fossil characters of these rocks show that they are the same as those on which Lexington stands; but here, as well as along the base of House Mountain, they are softer, and not so extensively permeated with white veins, as they are around Lexington, where the crushing forces to which they have been subjected have not only tended to harden many of the beds, but have produced innumerable fissures that have been filled up by infiltration, and now present beautiful veins of calc spar. But the underlying coraline bed that forms the base of this epoch, and crops out so conspicuously near Lexington, is not brought to the surface at this point, yet is found at the distance of a few miles on both sides of our present line of section. I have, therefore, included it.

At the distance of two miles above the Baths, we come to the base of Hog-back Mountain,* at its northeast terminus, and about a mile northeast of where our section crosses. Here the North River cuts it off from what was once its northeast continuation, called Jump Mountain. The Medina sandstones (Rogers, No. IV) that crop out along the faces of the two ridges sink gradually as they approach the river—showing a marked depression at the point where the river has found its way through. Such, however, is not the case with the contiguous and nearly parallel ridge of North Mountain farther west.

The spurs of Hog-back and the face of the main ridge, to the height of several hundred feet, display an extensive outcrop of 4 *b*, *c* (Utica and Cincinnati shales.) These appear occasionally beneath the hard sandstones of 5 *a*, as we pass up through the wild, winding cañon that here gives passage to the waters that come down from the mountain valleys above, and meet at the upper entrance of the gorge to form the North River. Just where the river issues from the mountain pass, the stream separates into two parts, forming a small island, in the middle of which rises a spring of sulphur water, now known as Wilson's Spring. It evidently rises from the shales of 4 *b*, that here form the bottom of the river.

This is the point at which the turnpike leads us into "Goshen Pass," through which we follow the winding course of the river for several miles.

In pursuing his course through this crooked gorge the geo-

* This and Wolf Ridge, immediately in rear of it, have evidently been once connected with the two ridges of House Mountain, represented on the former section; though now separated by a beautiful valley three miles wide.

l student will find a problem to solve of no little com-
y, arising in part from the windings of the river, and in
reater part from the rupturing and faulting of the moun-
themselves. After passing the ends of both Hog-back
/olf ridges (see section) at the distance of about a mile
half above Wilson's Spring, he will find the course of the
nearly coincident with the strike of the Medina sandstones
ere dip so steeply on the N.W. face of Wolf Ridge as to
he lower beds beneath the stream, while those higher up
it through in the direction of their strike. Within view
point, and on the opposite side of the river, a great down-
om the next ridge (N. Mt.) has occurred, around which the
makes a loop of half-a-mile in extent; this slip, however,
te limited; for above, and on the right and left of the
mass the Medina sandstones again crop out along the
f the North mountain ridges with a moderate northwest-
ip, displaying their full thickness of about 500 feet along
ntheast face, and, with one slight undulation, and subse-
y increased dip passing beneath the Little Goshen valley
d.

er careful and repeated examinations of this portion of
Pass," Dr. Ruffner and myself agreed that the phenomena
ted could be accounted for only upon the hypothesis of
t running parallel with the axis of the mountain chain.
ted observations since our original survey have tended to
n the conclusions originally formed.

following the course of the loop in the river, mentioned
, we travel a short distance with the strike of the rocks
l the southeast, then turn and cross the fault (filled up
the débris from the face of the broken mountain), and
change our course to the northeast again following the
f strike in nearly an opposite direction, and passing be-
the outcropping sandstones that rise far above our heads.
e soon deviate from this course to one at right angles to
ountain, and by which we are conducted through another
l section of 5 *a*, *b* and *c*, and apparently pass out, right
the beds of Devonian shales. At the base of the mountain,
er, from the gap of which we have just issued, 7 and 8
ncealed from view, as evinced by the fact that they crop
many points along the base of the mountain at some dis-
from the road on both right and left. In this Little
n valley there are indications of extensive beds of limon-
es, some of which were worked many years ago. They
und in both 5 *b*, *c*, and in 8.

s valley offers no special facilities for studying the Devon-
ales, which are found much more fully and favorably
ed farther west, but along its western border for a distance

..pike, in a northeasterly direc-
. .ts of 7 and 8 are found along
. Furnace (or Knob) Mountain,
Big Calf-pasture, the chief fork
. .an the Great Goshen valley on
. y well-defined arches of 5 a, are
.ss up the river, while on the left
. . . rocks are overlaid by a bed of
. .and is the one represented on the

. . .ntain lies Goshen Valley, a beau-
. . one that presents some points of
. readily reached by the student of
..ses near the Cold Sulphur Springs
. . . Goshen depot on the Chesapeake
.aters of these springs flow from ex-
. . slightly toward the Mill Mountain
.his valley, as well as throughout this
. Period (6) is but indistinctly represented.
. .iferous Group (9a, b, c), appears to be
.the very fossiliferous limestones of the
. .he sandstones of the Oriskany Period
. . Craigsville, nine miles northeast of
. ., where a beautiful encrinal marble is
.so at points nearer to Goshen. Just
. . Mill Mountain (through which both
.ass), at several points a short distance
. .ntain, good exposures may be found.
.is point, is cut by Mill Creek, and its
. . exposed in the form of a closed anti-
. the northwest so as to give all the
. .

. Valley we must observe the fact that,
. Cold Sulphur, the upper member of
. .d in many places a large portion of
. .s also disappeared. There is a ridge
. . or less north of the depot, on which all
. .pear. I have not found what remains
. .50 or 500 feet any where in this valley.
. section west of Panther Gap we find
.to have increased and the lithological
. . .ome some modifications. Beds vary-
. . to argillaceous sandstones are found
. . ., as may be seen both on the railroad
. . quantities of these rocks have been
. .near Millboro depot. Calcareous con-
. .m, full of veins of infiltrated carbonate

lime (*septaria*), increase in size and number; while thin beds fossil limestone, especially in *a*, are occasionally exposed to ›w.

At Millboro depot a line of stages leaves the railroad for the arm Springs, fifteen miles to the west. At the distance of o miles we reach the old Millboro Springs where we again d sulphur water rising from the Devonian strata (10). ıother mile brings us to the famous "Blowing Cave," where is well worth while for the explorer to allow himself at least e full day. He is now upon the banks of the Cow-pasture ver, one of the upper forks of the James. Here the river ts through a ridge (Cave Hill), exposing to view an arch of ›lderberg limestone (7) into which a cavern of unknown depth tends from which a breeze of considerable force issues conıually in warm weather. Above the limestones is a second ›h of Oriskany sandstone (8), in which are numerous Spirifer ells well preserved. These two formations may be studied re with great convenience; and, if an additional exposure is sired, it may be found two miles farther toward the north-›t, where Stuart's Creek exposes a similar arch in the same l, and where fine specimens of Favosites are easily obtained. Exposures of the members of 10 may be studied along the nks of the Cow-pasture both above and below the passage ›ough Cave Hill. A short distance below, in what is called lum Bank," we found a thin bed of limestone remarkably l of fossil shells. At other points higher up and lower down › river similar exposures occur.

Near this place is one of the numerous so-called "Alum rings"—the *Wallawhatoola*, an old Indian name. The waters re, as at the Rockbridge and the Bath Alum Springs, collect ›wly from the crevices of the dark pyritous shales of No. 10. rings of this class are very numerous among the Devonian ales in Virginia; and waters of similar character sometimes ue from shales of earlier and later dates. Their chief minıl constituents are sulphates of alumina, lime, magnesia, tassa, soda, iron (*ferrous* sulphate), with more or less *free* sulıuric acid. In the Wallawhatoola I found, with the spectro›pe, a decided trace of lithia.

The shales of this region, and especially in this valley of › Cow-pasture River, present three tolerably well character›d beds; the equivalents, no doubt, of the three recognized ochs of the Hamilton Period*—Marcellus, Hamilton and ›nesee. The lower member consists of dark—sometimes ıck, sometimes bluish-black—shales that split readily into in layers, and even fine scales or slender columnar fragments. ıe middle member has a decidedly greenish tint—olive in

* This is No. VIII of Professor Rogers's series.

many places, especially where it appears along the public roads, and in cuts on the railroads. The highest division is much variegated in color and texture; the beds of shale are yellow, brown and red, while considerable strata of sandstone of argillaceous character are found alternating with the shales.

Among all these are found beds of very calcareous shales passing often into impure limestones that abound in Encrinites, Atrypas, Spirifers, etc. The upper member has generally more calcareous beds in it than either of the others. This whole region has been greatly denuded, but the sharply rounded, and often cone-like hills that are left standing, with deep ravines cut out between them, present a striking feature of the landscape, and, at the same time, afford the means of an approximate estimate of the thickness of the whole series of shales, which cannot be less than seven hundred feet.

Along the faces of many of the hills that have been recently denuded by floods in the river and its tributaries, the planes of stratification, and of slaty (metamorphic) cleavage, are both well displayed—the latter so distinct that an unpracticed eye might readily mistake them for the planes of original stratification.

About four miles west of the Blowing Cave the turnpike crosses a ridge called Mair's Mountain, capped by a low arch of Oriskany sandstone (8), beneath which are exposures of the Helderberg limestones (7) where a small stream has cut its way through the ridge. Beyond this ridge we find another synclinal trough filled with the shales of No. 10, out of which rise the waters of the Bath Alum. Near this watering place is a cave formed by the washing out of the softer bed of Medina rocks so as to leave a regular arch which becomes narrower and lower toward the rear of the cavern, giving the whole cavity the shape of a semi-cone with the dividing plane for the floor. This is an object of interest to visitors. Its location is beneath the ridge, marked "Piny Ridge," on the section.

A mile beyond the Bath Alum, our line begins to ascend the lofty ridge of the Warm Springs Mountain. To the structural geologist this presents an object of the highest interest. As we follow the windings of the turnpike we find ourselves surrounded first by the débris of the Clinton sandstones and shales (6 and 7 are concealed), and as we approach the crest of Piny Ridges the Medina sandstones (5 *a*) make their appearance *in situ.* We are thence conducted by a spur across to the face of the main ridges, where the road is cut out of the sandstones, exposing their lithological and fossil features in a very interesting way. Ripple marks and casts of shells in the brown and purple sandstones, and fucoids in the shales, are of frequent occurrence.

On reaching the depression of the summit where the road

crosses, we turn to the left and follow the crest of the ridge for half a mile toward the southwest to the top of what is known as "flag rock"—the highest outcrop of Medina sandstone on this mountain, having a steep southeasterly dip. From this point, 3340 feet above tide level, the mountain scenery on all sides is very grand. Along the base of this ridge, on the northwest side, lies the Warm Springs Valley—a narrow strip of the Lower Silurian limestones of the Great Valley again brought to the surface. On the opposite side of this narrow valley another ridge, Little Mountain, rises to a less elevation, but is composed of the same kind of rocks as the main mountain, but dipping toward the northwest.* The olive-colored sandstones, generally found at the base of the Medina group in this region, appear near the summit of both these opposing ridges, and are succeeded by the fragile sandstones and shales of the Cincinnati and Utica epochs that form the steep slopes of both mountains. These are succeeded by the Trenton (4 *a*) limestones that dip beneath them, but form more gradual slopes toward the middle of the valley, where the older Chazy (3 *c*) limestones make their appearance. The latter are not largely developed where the tepid waters of the Warm Springs rise, but widen out considerably toward the southwest. A short distance to the northeast of the springs we found Trenton fossils in abundance, like those we had found just below the entrance of Goshen Pass.

In this anticlinal valley the Lower Silurian rocks come to the surface for a distance of several miles on both sides of the section, the general range being parallel with the Appalachian chain.

The two ridges that here face each other were doubtless parts of a great open anticlinal fold that was formed, when, by powerful lateral pressure from a southeasterly direction, the strata were pushed up from their original horizontal bedding. But it is hardly probable, judging from the present condition of things, that they ever formed complete arches across the valley. It is certainly more reasonable to suppose that such masses of strata of varying hardness and strength, and with an aggregate thickness of more than two thousand (2000) feet, were so ruptured at the time of upheaval as to form a rugged gorge, extending for many miles along the crest of the fold, and that subsequent erosions and denudations by ice and water widened it out, and shaped it into the beautiful valley as we now find it. This is a valley of thermal waters; for, besides the Warm Springs, near which our section crosses, and the baths of which range in temperature from 95° to 98° F.; the Hot Springs, five miles to the southwest, with temperatures varying from 100° to 108° F., and the Healing Springs in the same

* Along some parts of this broken ridge the sandstones are vertical or even inverted.

neighborhood, with a temperature of 85°, rise in the same anticlinal fold.

About half a mile southwest of the Warm Springs the collected waters of this portion of the valley find their way out in a northwesterly direction through a deep ravine, in which are found exposures of all the formations from 4 to 8.

General remarks.—(1.) Throughout the whole region represented on the accompanying section, conformity of strata prevails, and so continues till we reach the Carboniferous in West Virginia. (2.) The Medina sandstones that are from 405 to 500 feet thick along the North Mountain thin out to about 350 on Warm Springs Mountain. Here, too, the structure is less conglomerate, and the marks of shore-line formation are less numerous and distinct than they are farther east. (3.) It may be well to mention some of the prominent points along the line of section convenient for observation. At the lower entrance of Goshen Pass, and in Warm Springs valley, exposures of 4 may be readily found. No. 5 (Medina) may be successfully studied in Goshen Pass and on Warm Springs Valley; while the region around Millboro Springs affords to the explorer some of the finest exposures of 7, 8 and 10. But the accompanying section may serve as a key to a wider range of observation. Perhaps the best point of departure would be Goshen, on the C. & O. Railroad. If he wishes to extend the section farther toward the northwest, the turnpike from Warm Springs to Huntersville, in West Virginia, affords a favorable route for horse-back explorations.

Washington and Lee University, Va., April, 1879.

ART. XX.—*On the Discovery of a supposed new Planetoid;* by Prof. C. H. F. PETERS. From a letter to the Editors dated Litchfield Observatory of Hamilton College, Clinton, N. Y., July 13, 1879.

THE following are the results of two observations on a planetoid found here on the 9th inst., which seems to be new.

1879.	Mean time.	α (198).	δ (198).	No. of comp.
July 9.	$11^h\ 36^m\ 48^s$	$17^h\ 22^m\ 11^s{\cdot}16$	$-23°\ 22'\ 7''{\cdot}2$	4
July 10.	12 32 24	17 21 21·15	−23 27 29·5	8

Comparison star for both evenings was θ Arg. 16826. Last night I succeeded again in getting a good set of observations, which, however, are not yet reduced. The planet is rather of the fainter class of the 11th magnitude, and on account of its southern position a difficult object, if the sky is not quite serene.

Should the planet of Mr. Palisa of May, after the final discussion of the observations, turn out to be a new one and not identical with *Adeona*, the present one will be number 199.

ART. XXI.—*Notes on the Laramie Group of Southern Colorado and Northern New Mexico, East from the Spanish Ranges*; by JOHN J. STEVENSON, Professor of Geology in the University of the City of New York.

THE most southern of the Laramie coal fields along the eastern base of the Rocky Mountains lies partly in Colorado, and partly in New Mexico. It is rudely lozenge-shaped and has its greatest breadth near the southern boundary of Colorado, whence it tapers in each direction, pointing out at the north near Cucharas Creek, forty miles from the state line, and terminating at the south immediately beyond Cimarron Creek, thirty-six miles south from the Colorado line. Its area is not far from 2200 square miles, and the whole of it, save perhaps 150 square miles, is included in the district examined by me during the season of 1878. With consent of the Chief Engineer, U. S. A., a brief synopsis of results is offered here in advance of the report to be presented to Lieutenant Wheeler.

This field is separated from the Spanish Ranges by a meridional valley, from one-fourth of a mile to nearly two miles wide. Its eastern border is well-marked by a line of high bluffs, facing the plains and showing the lower rocks of the Laramie resting on the higher shales of the Colorado group. The extreme breadth along the state line is due to the presence of a basalt plate covering the Raton* Plateau, whereby the rocks have been protected from erosion, so that the lower members of the group reach to, say, twenty-three miles south of east from Trinidad, Colorado. No part of the Laramie group exists on the Purgatory or the Canadian Plains north or south from the plateau, west from longitude 104° 7′, or south from north latitude 37° 20′; but the Middle Cretaceous rocks, those at the base of Cretaceous No. 4, immediately underlie the Quaternary deposits on those plains and extend for several miles up all of the cañons on the eastern side of the coal-field.

Three petty anticlinals were traced out as affecting the Laramie beds. They are important, economically, as they keep the coals within reach.

The Laramie group is represented here by sandstones, shales and coal beds. The sandstones, with few exceptions, are yellowish-gray, and each is an almost exact copy of every other, the only material variations being in thickness. Persistent limestone beds, with marked characteristics, are wholly wanting, and such beds as do occur are thin, irregular and featureless. No rock exists which can be used as a horizon, so

* This is designated the Chicorica Mesa on Dr. Hayden's general map of Colorado.

that the process of tying together the fragmentary local vertical sections is a painful one. But the cañons crossing or deeply indenting the field are numerous and are separated by narrow intervals; they afford ample opportunity for verification of the sections, and it seems hardly possible for serious errors to escape detection.

The section of the group is approximately as follows:

1. Great Sandstone, 440′
2. *Coal bed* Z, Blossom.
3. Sandstone and shale, 77′
4. *Coal bed* Y, Blossom.
5. Sandstone and shale, 75′
6. *Coal bed* X′, 2′
7. Shale and sandstone, 45′
8. *Coal bed* X, 4′
9. Sandstone and Shale, 26′
10. *Coal bed* W, 6′ to 4″
11. Sandst'e and Shale, 47′ to 70′
12. *Coal bed* V, 4′ to 10″
13. Sandst'e and shale, 30′ to 36′
14. *Canadian coal bed* U, 6′ to 4″
15. Sandst'e and shale, 20′ to 30′
16. *Coal bed* T, 6′ to 2′ 6″
17. Sandst'e and shale, 13′ to 20′
18. *Coal bed* S, 4′ 3″ to 10″
19. Sandstone and shale, 25′
20. *Coal bed* R′, 1′ 4″
21. Shale and sandst'e, 25′ to 35′
22. *Caliente coal bed* R, 16′ to 1′
23. Sandst'e and shale, 30′ to 35′
24. *Raton coal bed* Q, 8′ to 1′
25. Sandstone and shale, 25′
26. *Coal bed* P, 2′ 6″ to 1′
27. Sandst'e and shale, 40′ to 50′
28. *Coal bed* O, 10″
29. Sandstone and shale, 30′
30. *Coal bed* N, 2′
31. Sandst'e and shale, 33′ to 43′
32. *Cameron coal bed* M, 33′ to 4″
33. Sandst'e and shale, 22′ to 27′
34. *Coal bed* L, 1′ to 8″
35. Sandst'e and shale, 64′ to 70′
36. *Coal bed* K, 3′
37. Sandstone and shale, 24′
38. *Coal bed* J′, Blossom.
39. Sandst'e and shale, 44′ to 52′
40. *Long's cañon coal bed* J, 8′ to 1′
41. Sandst'e and shale, 45′ to 83′
42. *Coal bed* I, 2′ 6″ to 2″
43. Sandstone and shale, 50′
44. *Coal bed* H′, 1′
45. Sandst'e and shale, 50′ to 60′
46. *Cat's Claw Cañon coal bed* H, 5′ to 2″
47. Sandst'e and shale, 90′ to 111′
48. *Upper Vermejo coal bed* G, 2′ to 2″
49. Sandst'e and shale, 60′ to 120′
50. *Lower Vermejo coal bed* F, 9′ to 4″
51. Shale, 12′
52. *Coal bed* E″ 1′
53. Shale and sandstone, 15′
54. *Coal bed* E′, 6″
55. Shale and sandstone, 25′
56. *Upper Reilly coal bed* E, 7′ 8″ to 2″
57. Sandst'e and shale, 18′ to 31′
58. *Lower Reilly coal bed* D, 6′ to 2″
59. Sandst'e and shale, 12′ to 54′
60. *Willow Creek coal bed* C, 3′ 6″ to 1′
61. Sandst'e and shale, 76′ to 100′
62. *Trinidad coal bed* B, 16′ 6″ to 1′
63. Sandst'e and shale, 20′ to 45′
64. *Dillon coal bed* A, 16′ 6″ to 1′
65. Shale, 1′ to 10′
66. Halymenites Sandstone, 50′ to 80′
67. Shale and sandstone, 70′

The total thickness of the group, as shown in this field, is not far from 1800 feet.

The Coal Beds.

Several coal beds, which seem to be of very limited extent, have been omitted.

The beds given in the section appear to be persistent, being shown wherever their horizons are exposed; though often only by "blossoms," which sometimes fail to indicate either the thickness or the quality of the coal. No bed was found certainly wanting at any locality, except where, during the formation of some enormous sandstone, the underlying rocks, shales as well as coals, had been cut away. But, though thoroughly persistent, the Laramie coal beds are as variable as are those of the Lower Barren coal group of the Appalachian coal field. Reference to the section shows that no bed exhibits any degree of constancy, and that even the best one is at times utterly worthless. None possesses more than merely local importance. A bed, ten feet thick at one place, may be but a few inches thick at another only a mile away, or its excellent coal may be represented by wretched shale, utterly worthless for fuel.

The variations in thickness of the beds and in quality of the coal point to instability of conditions; but this is more clearly shown by the splitting up of the larger beds, especially in the lower part of the section; a most perplexing phenomenon, where readily identifiable horizons of sandstone or limestone are altogether absent. This subdivision of the beds seems to be confined to the lower part of the section, yet it may characterize the higher part also. The higher coal beds are seldom thick and their variations cannot be traced without much difficulty, the more so because their exposures are indistinct, being masked by debris of the sandstones.

The breaking up of the lower beds along the western edge of the field is so extreme, that at some localities the section of the first two hundred feet above the Halymenites Sandstone bears no resemblance to the same part of the group as exposed on the eastern side of the field. At the head of the Vermejo cañon, this interval contains fourteen streaks of *coal*, and black shales are liberally distributed throughout the section. The *Cameron coal bed* splits up into sixteen layers of sandstone, shale and coal, not far below Cameron post office on Vermejo creek in the center of the field. There the aggregate thickness is thirty-three feet, though but a short distance east or west, the bed is barely two feet thick. The most interesting variations are those shown by the *Trinidad coal bed*, between Trinidad and Raton Pass, within a distance of little more than nine miles. Four measurements gave the following results:

1. *Coal*,	0′ 8″	0′ 8″?	0′ 10″	4′ 0′
2. Interval,	7′ 0″	8′?	21′ 10″	24′ 0′
3. *Coal*,	1′ 8″	0′ 4″	3′ 0″	5′ 0′
4. Interval,	0′ 2″	0′ 4″	14′ 0″	13′ 0′
5. *Coal*,	5′ 0″	5′ 5″	6′ 0″	9′ 6′
6. Interval,	0′ 4″	1′ 4″	8′ 0″	12′ 0′
7. *Coal*,	2′ 0″	0′ 8″	1′ 0″	1′ 0′
Total,	16′ 10″	16′ 7″	54′ 8″	68′ 6′
Total of *Coal*,	9′ 10″	7′ 5″	10′ 10″	19′ 6′

The interval, No. 2, is filled with shale in the first two sections, but contains sandstone as well as shale in the last two. No. 4 is *bony coal* in the first two, but holds shale and sandstone in the last two. No. 6 is filled with clay at all of the localities.

The *coal* from the Laramie group in this field is soft. That from the *Trinidad bed* is excellent gas-coal and the slack is easily coked. The coking is done in bee-hive ovens similar to those used in western Pennsylvania. Little has been done, away from Trinidad, toward developing the mines. The whole country is cursed with old Mexican land grants, most of which are clouded, so that capitalists hesitate to make investments.

The Sandstones.

The sandstones are much alike and few of them are persistent. They change into shales and back again into sandstones in the most perverse manner. Still, some of these beds are constant and are serviceable locally as guides.

The Great Sandstone, closing the group within this field, is present at the summits of all divides and is readily recognized by its physical peculiarities. It is yellowish gray, compact, and for the most part comparatively fine-grained, though it occasionally contains a layer of not very coarse conglomerate. This rock is wholly non-fossiliferous at every locality where it was examined.

The sandstones above *coal beds* F, G and H, are usually present. These vary from light yellowish gray to decided buff. Ordinarily they are massive, but occasionally flaggy layers are found in which impressions of dicotyledonous leaves abound. No animal remains were observed except in the sandstone overlying *coal bed* F, in which obscure impressions of a *Cardium* were observed at one locality.

The *Halymenites sandstone*, at the base of the series, is comparatively fine-grained, usually gray, sometimes yellowish gray. It is invariably present and forms a distinct gray band on the bluffs from Cucharas Creek southward to Cimarron Creek, with the blossom of the *Dillon coal bed* almost immediately above it. I have given its name because the rock is loaded with *Halymenites major* Lesqx., which was not identified with certainty at any higher horizon within this field ; though it is abundant at higher horizons in other fields farther north.

Almost without exception, the sandstones are fine-grained at

the eastern edge of the field, but they become coarser toward the west, until on the western border, some of them are conglomerates and the shales have almost wholly disappeared. This condition exists at the base of the mountains.

Limestone layers were seen within several of the sandstones. They are always present on the eastern side of the field in the intervals between *coal beds* F and G, H and I, and I and J. Similar layers are sometimes shown in other intervals, but they are not persistent. These beds are from two to eighteen inches thick. None was found above *coal bed* J, which is about midway in the section. The limestone is blue to flesh-colored, weathers yellow because of much iron, and contains no fossils. It is very similar to much of the limestone found in the Lower Barren coal group of the Appalachian coal field.

Impressions of leaves of dicotyledonous plants were found in all the flaggy sandstones from the *Dillon coal bed* to the base of the Great Sandstone at the top of the section; but animal remains are rare. Some fish-teeth were obtained from the Halymenites Sandstone, associated with a *Cardium*, which is very similar to a shell of which imperfect impressions occur in the sandstone overlying the *Lower Vermejo coal bed.* But no impressions of leaves were found in the shales immediately overlying *coal beds.* The impressions occur only in sandstones; they are of isolated or fragmentary leaves and many of them were much softened by soaking before they were entombed. The plants belonged to upland vegetation and their leaves were evidently brought down to the shore by streams.

Relation of the Laramie to the Middle Cretaceous.

Throughout this southern coal-field the Lamarie rocks rest on the shales of the Fort Pierre sub-group, the Cretaceous, No. 4 of Mr. Meek's original section. These contain *Ammonites placenta*, *Baculites ovatus*, *Inoceramus convexus*, and other thoroughly characteristic species. The Fox Hills group, the No. 5 of Mr. Meek's section, appears to be wanting here. It certainly is wanting if the *Halymenites sandstone* is to be included in the Laramie group.

Lithologically, the transition from the Fort Pierre to the Laramie is so gradual that the line of separation between the groups must be assumed arbitrarily. The dark shales of the former pass upward into brownish shales with thin sandstones, which in turn shade away into the *Halymenites sandstone* above. The transition requires not far from two hundred feet of rock.

But a great change took place at the close of the Fort Pierre group. For the most part, the shales of that group are rich in animal remains, but such remains cease to appear at forty or fifty feet below the line assumed as the summit. Animal remains are, to all intents, absent from the Laramie group in the Trinidad

coal-field. The newer conditions were unfavorable to animal life. Marine conditions, however, did not cease with the Fort Pierre. The sandstones of the Laramie are of marine origin, though perhaps only off-shore deposits. *Halymenites major* occurs profusely in the lowest sandstone within the Trinidad field as well as at much higher horizons in the Cañon City field. Huge knotted fucoids were found in a sandstone above *coal bed* J, in the former field. Other sandstones, showing no fucoids, contain many battered logs. Limestones, unmistakably of marine origin, occur up near to the middle of the Laramie. The change is not unlike that shown in the passage from the Lower to the Upper Carboniferous in the Appalachian coal-field.

ART. XXII.—*On some points in Lithology*; by JAMES D. DANA.

II. ON THE COMPOSITION OF THE CAPILLARY VOLCANIC GLASS OF KILAUEA, HAWAII, CALLED PÉLÉ'S HAIR.

THE capillary volcanic glass of Kilauea collected by the writer at the volcano in the year 1840 was analyzed for the writer's Geological Report of the Exploring Expedition (1849) by Prof. B. Silliman (B. Silliman, Jr.), and the results are published in it on page 200. The large discrepancies between the two analyses there reported—one of a dark and the other of a pale variety—and especially the difference as to soda, one being stated to contain 21·62 per cent, and the other none, left the question of composition in great doubt.* I have now to report two new satisfactory analyses of the glass. For these, science is indebted to Mr. F. J. Allen of the Sheffield Scientific School of Yale College, excepting the determination of the state of oxidation of the iron, which is by Prof. O. D. Allen. The results were as follows:

	I.	II.	Mean.
Silica	50·76	50·74	50·75
Alumina	16·68	16·39	16·54
Iron sesquioxide	2·15	2·05	2·10
Iron protoxide	7·90	7·87	7·88
Manganese protoxide	*trace*	*trace*	*trace*
Magnesia	7·65	7·65	7·65
Lime	11·95	11·97	11·96
Soda	2·11	2·16	2·13
Potash	0·55	0·57	0·56
Ignition	0·35	0·35	0·35
	100·10	99·75	99·92

* The analyses also of volcanic scoria and lava, given on the same page of my Report, are evidently too uncertain to be longer quoted, unless the results shall be confirmed by other analysts.

Γhe composition obtained has great interest, since it shows ıt this most fusible part of the Kilauea lavas has almost pre· ely the composition of ordinary doleryte (=basalt=diabase, entially). I cite for comparison an analysis by G. W. Hawes the "trap" of West Rock (New Haven, Conn.), which agrees sely with the average composition of this basic rock.

	SiO_2	AlO_3	FeO_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	ign
's Hair	50·75	16·54	2·10	7·88	*tr.*	7·65	11·96	2·13	0·56	0·35=99·92
st Rock "trap"	51·80	14·21	3·55	8·26	0·42	7·63	10·68	2·15	0·39	0·63=99·72
										[+phosphoric acid 0·14

Γhe "trap" consists of labradorite and augite with some gnetite. It is hence identical with the most abundant kind igneous rocks. The fusibility of such a compound is thus ll indicated by the facts at Kilauea. Moreover it is not sur-sing, since the fusibility of both labradorite and ordinary ck augite are each marked down as low as 3 by von Kobell. ere is hence no question as to the complete fusion of such redients in a volcano, even where moisture is not present.

Γhe analyses add another to the many examples already own, proving that there was no difference in constitution ween a large part of the material in fusion and ejected in sozoic time and that thrown out by modern volcanos; and it ıstrates the fact that Geology has no good basis for the dis· ction of "older" and "younger" among igneous rocks.

An important paper on the microscopic characters of Pélé's ir has been published at Tubingen (in 1877) by C. Fr. W. ukenberg, in a pamphlet giving also the results of the author's estigations on Tachylyte and Hyalomelan, Basalt glass, rous and Spherulitic Basalt, and Obsidian. He states, and ıstrates by figures, the following facts respecting Pélé's Hair. e fibers are sometimes bent and coalesced into loops; often tubular; frequently contain air bubbles, and occasionally crolites. There is usually an enlargement of the diameter enever a crystal (or microlite) exists within, and also about ny of the air-cavities. The crystals are mostly rhombic, but to their kinds the author makes no suggestion.

T. XXIII.—*On the size of Molecules;* by N. D. C. Hodges.

F we consider unit mass of water, the expenditure on it of amount of energy equivalent to 636·7 units of heat will ıvert it from water at zero into steam at 100°. I am going consider this conversion into steam as a breaking up of the ter into a large number of small parts, the total surface of ich will be larger than that of the water originally. To rease the surface of a mass of water by one square centimeter

requires the use of ·000825 milligrams of work. The total superficial area of all the parts, supposing them spherical, will be $4\pi r^2 N$. The number of parts being N, the work done in dividing the water will be $4\pi r^2 N$. For the volume of all the parts we have $\frac{4}{3}\pi r^3 N$. This volume is in accordance with the requirements of the kinetic theory of gases, about $\frac{1}{3000}$ of the total volume of the steam. The volume of the steam is 1752 times the original unit volume of water.

$$\text{Hence } \tfrac{4}{3}N\pi r^3 3000 = 1752$$
$$4N\pi r^2 \cdot 000825 = 636 \cdot 7{,}423$$

One unit of heat equals 423 milligrams.

Solving these equations for r and N, we get r equal to ·000000005 centimeter, a quantity of the same order of magnitude as has already been obtained by Thomson, Maxwell and others, N equal 9000 (million)$^3 n$ for the number in one cubic centimeter 5 to 6 (million)^3.

Around every body there is an atmosphere of more or less condensed gases. On the surface of platinum these must be nearly in the liquid condition, as shown by the power of platinum to bring the atoms of hydrogen and oxygen so near together that they combine. These vapors on the surface have a tendency at ordinary temperatures to expand; and part of them can do so, if the surface of the body is reduced. There is in these condensed atmospheres an explanation of all the phenomena of superficial tension. The energy in the unit of area ought to be equivalent to the amount of work done in compressing a quantity of the vapor from the gaseous to the liquid state sufficient to cover the surface a few molecules deep. The molecular attraction seems to be very slight in gases, when the molecules are ten or fifteen molecular diameters apart. To get some idea of the amount of work done in compressing one gram of oxygen to liquid form, we may consider that in the union of one gram of hydrogen with eight grams of oxygen 34,462 units of heat are produced. It matters not that the condensation is brought about by the energy of chemical separation rather than by the work done in pressing them together in a cylinder.

The superficial energy of platinum is 169·4 milligrams per square meter or ·01694 per square centimeter, equal to ·00004 of a unit of heat. The proposition

$$9 : 34{,}462 = x : \cdot 00004$$

gives the weight of water condensed on square centimeter of surface or the volume in cubic centimeters as ·00000001, which agrees with the other result.

Physical Laboratory, Harvard College, May 14, 1879.

ART. XXIV.—*Discovery of a new group of Lower Carboniferous Rocks in Southeastern Ohio;* by E. B. ANDREWS. Letter to the Editors dated Lancaster, Ohio, July 5, 1879.

I HAVE recently found in Perry County (Ohio) an interesting group of fossiliferous rocks between the Maxville Limestone (the approximate equivalent of the Chester group of Illinois), and the Waverly. In Illinois and along the Mississippi river, there are three distinct groups of Lower Carboniferous rocks between the Chester and the Waverly or Kinderhook of the Illinois Reports. These are the St. Louis, Keokuk and Burlington. It has long been my hope to find traces of these groups in Ohio. At one point I have recently obtained the following section:

Maxville limestone,	15 to 18 ft., estimated.
Coarse sandstone,	2 ft.
Clay shale, blue and red,	8 ft.
Horizon of nodular concretions, fossiliferous.	
Clay shale, blue,	7 ft.
Ferruginous limestone, highly fossiliferous,	15 in.
Blue clay shale,	8 to 10 ft.
Fine grained sandstone (Logan sandstone) Upper Waverly.	

At another locality, about a mile distant, I find the same intermediate group, but the Maxville limestone is not seen.

A few of the fossils first obtained were sent to Mr. R. P. Whitfield, who found them mostly new, but indicating a Keokuk type, with suggestions of Warsaw and Spergen Hill. I have since largely increased my collection and may have sixty or seventy species, and shall doubtless obtain many more. Besides corals and Bryozoa, which are beautifully preserved, I find representatives of the following genera: Lingula, Discina, Productus, Chonetes, Spirifer, Rhynconella, Phillipsia, Bellerophon, Aviculopecten, Platyceras, Dentalium, and of several others. Fragments of Crinoids are abundant, but, as yet, I I have found none whole. Very few of the species can be found in the underlying Waverly, and perhaps none in the overlying Maxville. I have been unable to identify many of the species with those figured in our Western Reports from the Lower Carboniferous rocks. It is probable that the newly found group does not exactly represent any of the groups found farther west, but shows the life that existed along the eastern shallow margin of the interior sea in which were deposited the vast calcareous beds of the Middle Lower Carboniferous, found along the Mississippi river. Provisionally the group may be called the Rushville group.

ART. XXV.—*Note on the Lower Waverly Strata of Ohio;* by EDWARD ORTON, Professor of Geology in Ohio State University, Columbus, Ohio.

THE Waverly Black Shale of Southern Ohio proves to be a very persistent stratum. It is but sixteen feet on the Ohio River, where it was first described by Professor E. B. Andrews, and at no point has it been found to exceed thirty feet in thickness, but it stretches without interruption from the Ohio River to Lake Erie, and now that it has been followed through the length of the State, it gives us the means of synchronizing the hitherto discordant elements of the lower part of the Waverly Group in a surprisingly satisfactory manner.

The identity of the Waverly Black Shale of Southern Ohio and the Cleveland Shale of Northern Ohio, which was suggested as probable ten years since by Dr. Newberry, and which has since been adopted by most of those who have written on the geology of the Waverly Group in Ohio, proves to be an error.

Dr. Newberry has since shown that the Erie Shale wedges out as it is followed westward from Cleveland, letting the Cleveland Shale down upon the Huron Shale, near the mouth of Vermillion River. From this it would appear that the Black Shale that is followed southward from that point covers the interval occupied by three northern formations viz: the Huron, Erie and Cleveland Shales.

The Waverly Black Shale finds its place directly above the Berea Grit to the northward. The stratum has been distinctly described in the reports on the northern counties, but it has not been distinctly named. It has been treated of as the dark, fossiliferous shale at the base of the Cuyahoga Shale. No better name could be found for it than Berea Shale—for it makes the roof of the Berea quarries, just as it does of the lower Waverly quarries of Pike County.

As a result of this determination, it is seen that we have in the Berea Grit a stratum that can be traced continuously from the Pennsylvania line westward to Erie County, and from thence southward to the Ohio River. The equivalence of the several principal subdivisions of the series in Northern and Southern Ohio is now apparent. Thus we find that the Bedford Shale is the Waverly Shale of Pike County, the Berea Grit is the Lower Waverly of Central and Southern Ohio, the Berea Shale (base of the Cuyahoga Shale) is the Waverly Black Shale, and the Cuyahoga Shale of the northern counties is represented by just about the same measure and the same character of beds in Pike County that it has at the north.

At about four hundred feet above the Great Black Shale,

certain highly fossiliferous beds occur. They have been worked for fossils quite carefully in Medina, Ashland, Licking, Ross, Pike and Scioto Counties. It seems probable, at least, that the Lodi, Ashland, Granville and Sciotoville fossils all come from the same horizon.

The Buena Vista Stone, that overlies by a few feet the Waverly Black Shale on the Ohio River, and with which the Berea Grit of Northern Ohio was identified by the erroneous reference of the Waverly Black Shale named above, proves to be much more local in its character than the other elements. It has not been found to hold as a continuous stratum as far north as the center of the State.

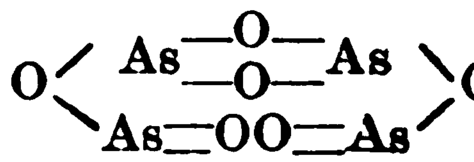
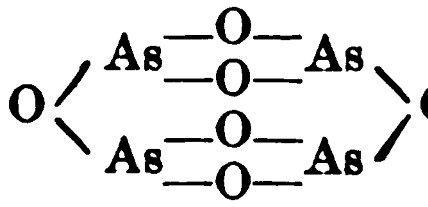
A summary of the facts here given is appended in a tabular form. The thickness of the several strata as found in Northern Ohio is that given by Dr. Newberry—while Southern Ohio is represented by the typical Waverly section.

Northern Ohio.	*Southern Ohio.*
Cuyahoga Shale, 150–250 ft. Upper beds fossiliferous.	Shale and Sandstone, 300–400 ft. Upper beds fossiliferous.
(Berea Shale,) 10 ft. Included by Newberry with Cuyahoga.	Waverly Black Shale, 15 ft.
Berea Grit, 60 ft.	Waverly Quarries, 60 ft. and overlying blue shale.
Bedford Shale, 75 ft.	Waverly Shale, 90 ft.
Cleveland Shale.	Great Black Shale.

A conglomerate covers the Cuyahoga Shale both in Northern and in Southern Ohio. It has been pronounced in both sections the Carboniferous conglomerate, but in Licking, Knox and other counties, the same fossiliferous stratum that underlies it constitutes the base of the Waverly conglomerate of Andrews, which is there separated from the Carboniferous conglomerate by one hundred to two hundred feet of the Logan sandstone of the same author. Without undertaking to clear up the confusion of the two conglomerates throughout the field, I venture to suggest that a satisfactory explanation for Southern Ohio seems to be found in the fact that upon the extreme western border of the coal-measures, the two conglomerates are unconformable by overlap, the Logan sandstone being greatly reduced and perhaps disappearing entirely, and the conglomerates thus coming to be considered as one.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *Vapor-densities at very High Temperatures.*—Victor Meyer proposed some time ago a simple method for the approximate determination of vapor-densities for the purpose of fixing molecular weights.* Subsequently, in conjunction with Carl Meyer, he extended the method to the determination of densities at temperatures just below the softening point of Bohemian glass, finding the density of phosphoric sulphide P_2S_5 to be 7·65, theory requiring 7·67; and that of indium chloride to be 7·87, the formula $InCl_3$ requiring 7·60, thus proving indium to be a perissad. These authors have now rendered their method available for much higher temperatures, optically a bright yellow, lying between the fusing points of cast and of wrought iron, by the use of bulbs of porcelain, heated in a Perrot's gas furnace. The operation is conducted precisely as at lower temperatures, some details only requiring modification. The temperature of the muffle was determined calorimetrically by means of a block of platinum; giving 1570° C., 1543° and 1557° in three experiments, the mean being 1560°. Sulphur-vapor at this temperature, was found to have a density of 2·17, S_2 requiring 2·21. As Deville and Troost found 2·23 at 1040° C., S continues to be diatomic at higher temperatures. The density as found by the authors below redness, 6·58, corresponds to a hexatomic molecule, S_6. Cuprous chloride, also determined in nitrogen, gave 7·05, the formula Cu_2Cl_2 requiring 6·84. Arsenous oxide gave a density of 13·80 at a moderate red heat, 13·78 at 1560°; corresponding to the formula As_4O_6, which requires 13·68. This agrees with Mitscherlich's results and shows that the opinion of Kolbe that arsenous oxide would split up like sulphur, into smaller molecules at higher temperatures, is not correct, the formula being As_4O_6 alike at 571° and 1560°. Its constitution must therefore be either  or . Cinnabar gave a density of 5·39, the formula Hg_2S_2 requiring 5·34.—*Ber. Berl. Chem. Ges.*, xii, 1112, June, 1879.

G. F. B.

2. *Vapor-densities of Metallic Chlorides.*—Victor and Carl Meyer give, in a later paper, the results of some determinations by their method, of the vapor-densities of certain metallic chlorides. Stannous chloride, at the temperature of 619° in a bath of melted lead, gave 12·85; at 697°, 13·08. Hence its formula should be Sn_2Cl_4 which requires 13·06. Zinc chloride, determined at 891° and 907° in the Perrot-Wiesenegg muffle furnace, gave 4·53

* This Journal, III, xvii, 63, Jan., 1879.

and 4·61, $ZnCl_2$ requiring 4·70. Ferric chloride, in a lead bath heated to the boiling point of sulphur (about 447°) gave 11·14; and at 619°, 11·01, the formula Fe_2Cl_6 requiring 11·23. At higher temperatures, even at 697°, both ferric and aluminum chlorides lose chlorine.—*Ber. Berl. Chem. Ges.*, xii, 1195, June, 1879.

G. F. B.

3. *On Lead tetrachloride.*—FISHER has given some experimental evidence to prove the existence of a tetrachloride of lead. When lead dioxide is acted on by moderately strong hydrochloric acid, a yellow solution is obtained having a strong odor of chlorine, and easily decomposed by heat, evolving chlorine and depositing crystallized lead chloride. Alkalies and alkali carbonates, as well as earthy oxides and carbonates, throw down lead peroxide, as also do weak acids as acetic and boric. If no excess of hydrochloric acid is used, simple dilution with water precipitates the dioxide. For the analysis, lead dioxide was cautiously added to twice its weight of hydrochloric acid previously diluted with an equal volume of water. After a few minutes, the yellow solution was poured off from the precipitated lead dichloride. Twenty c. c. of this solution was allowed to flow into a solution of sodium acetate, producing a precipitate of lead dioxide. Twenty c. c. was also added to a definite volume of ferrous sulphate of known strength, in excess. The former mixture was then filtered into a Woulfe's bottle, the lead dioxide on the filter washed, dried, ignited and weighed. The latter solution was titrated with permanganate, the chlorine being estimated from the amount of the ferrous salt oxidized by it. Assuming the analytical reactions to be $PbCl_4+(H_2O)_2=PbO_2+(HCl)_4$ and $PbCl_4=PbCl_2+Cl_2$, it is evident that the lead obtained by the first of the above processes stands to the chlorine obtained by the second as 1 : 2 atoms. The experimental ratios obtained were 1 : 1·97, 1 : 2·03, 1 : 1·98, and 1 : 1·96, in several experiments; thus leaving no doubt that the yellow solution examined contained a compound of lead and chlorine in the proportion of one lead to four chlorine. The same body results when red lead is treated with HCl, and when chlorine gas is passed through a solution containing lead chloride in suspension. The facility of this conversion into peroxide in presence of sodium acetate leads the author to propose it as a quantitative method, using bromine in place of chlorine.—*J. Chem. Soc.*, xxxv, 282, June, 1879. G. F. B.

4. *On the New Element, Scandium.*—The new element scandium, discovered by Nilson, was obtained from a specimen of the ytterbia of Marignac, prepared from both gadolinite and euxenite. In order to ascertain whether the new element exists in both these minerals, or in only one of them, CLÈVE, engaged in the investigation of the gadolinite earths at the same time with Nilson, examined these especially for the new metal, and found, a few weeks after the discovery was announced by Nilson, that gadolinite contained it but only in minute quantity. From four kilograms of this mineral, he was able to extract 0·8 gram scan-

dium oxide; hence he infers that gadolinite contains 0·02 per cent of this earth. In studying the yttric earths of yttrotitanite or keilhauite from Arendal, he found scandia present there also. Three kilograms of this mineral gave him 1·2 grams of scandium oxide, corresponding to 0·04 per cent. He is now engaged on larger quantities of the keilhauite and hopes to obtain enough material to enable him to determine the more important characters of the new element, which he thinks does not belong to the yttrium group.—*Bull. Soc. Ch.*, II, xxxi, 486, June, 1879.

G. F. B.

5. *On the Action of Bleaching Powder on Ethyl Alcohol.*—Schmitt and Goldberg have studied the action which goes on in the commercial process for the preparation of chloroform by distilling together bleaching powder and ethyl alcohol. When a good bleaching powder acts on absolute alcohol, after seven to ten minutes an energetic reaction sets in with evolution of much heat, and there distills over, besides the excess of alcohol, a greenish yellow oil, which under the influence of light and heat decomposes almost explosively, evolving vapors of hydrochloric and hypochlorous acids. They have not succeeded in isolating this oil, but they believe it to be ethyl hypochlorite, formed by the reaction: $CaCl_2 + Ca(OCl)_2 + (C_2H_5OH)_2 = CaCl_2 + Ca(OH)_2 + (C_2H_5(OCl))_2$. The residue of the distillate after the explosion, consists about $\frac{4}{5}$ of alcohol and aldehyde, removable by water, and about $\frac{1}{5}$ of a non-miscible oil, heavier than water. Forty c.c. of this oil, obtained by the use of 415 c.c. alcohol, gave, on fractioning, 1 c.c. boiling below 70°, 4 c.c. between 70° and 80, 5 c.c. between 80° and 100°, 8·5 c.c. between 100° and 150°, 20·5 c.c. between 150° and 160°, and 1·5 c.c. between 160° and 180°. The largest fraction yielded a constant product boiling at 154°–155°, which was monochloracetal. The highest fraction gave dichloracetal. The fraction from 80° to 150° gave a product constant at 77°–78° which gave the formula C_3H_7OCl, probably chlormethyl-ethyl ether $\left.\begin{matrix} CH_2Cl \\ C_2H_5 \end{matrix}\right\} O$.—*J. prak. Ch.*, II, xix, 393, May, 1879.

G. F. B.

6. *On Heptane from Pinus Sabiniana.*—Thorpe has submitted to examination a hydrocarbon obtained by distilling the exudation of a Coniferous tree, *Pinus sabiniana* Dougl., or nut pine, growing in the Sierras of California. This hydrocarbon was first described in 1871 by Wenzell of San Francisco under the name "Abietene," it being found in commerce under the names abietene, erasine, aurantine, theoline, etc. Through the assistance of Dr. Squibb of Brooklyn, Thorpe obtained two gallons of this hydrocarbon from Wenzell. Its physical properties fully confirmed the statements of the latter. It was colorless, had a persistent odor of oil of oranges, boiled slightly below 100° and left a resin, which had the above odor very strongly. On agitating the oil with strong sulphuric acid, the acid became brown and the hydrocarbon lost its smell. Its boiling point, corrected, was

found to be 98·43° and 98·42° in two portions. On analysis it gave 83·81 carbon, 16·05 hydrogen, while heptane C_7H_{16} requires 83·97 carbon, 16·03 hydrogen. Its vapor density was found to be 50·07 and 49·94 in two experiments, C_7H_{16} requiring 49·90. Having so large a quantity of pure heptane, Thorpe undertook the determination of its physical constants. Three determinations of its specific gravity, reduced to 0° and referred to water at 0°, gave 0·70057. The coefficient of expansion between 0° and 100° is given by the formula $1 + 0·00121023t + 0·0000011133t^2 + 0·000000011 74t^3$. The volume at the boiling point 98·43°, is 1·14111. The specific gravity at this temperature is 0·61393 and its specific volume is 162·54, that calculated from Kopp's values being 165. Its refractive index was found to be 1·3879 at 17·6° for the sodium line. The specific refractive energy $\frac{\mu-1}{d}$, is 0·565; and its molecular refractive energy is 56·4, the value from Landolt's formula being 55·8. It appears to have a slight rotatory power +6·9′. Its coefficient of viscosity varies with the temperature, the value being given by the formula $\eta = 0·005003 - 0·0000055 01t + 0·0000000 3061t^2$. Its surface tension by the capillary tube method was found to be 22·19 C. G. S. units; and by the bubble method 21·8 and 21·12 units; giving 167 as the angle of capillarity. This surface tension is the lowest of any known liquid. Thorpe believes that this heptane is probably isomeric with that obtained from petroleum and probably identical with that from azelaic acid.—*J. Chem. Soc.*, xxxv, 296, June, 1879. G. F. B.

7. *On the Synthesis of Chrysene.*—GRAEBE and BUNGENER, struck by the similarity between chrysene and phenanthrene, formulated them analogously and suggested that the former might be a phenyl-naphthalene derivative, as the latter is a diphenyl one. By the action of Al_2Cl_6 upon a mixture of phenylacetic acid and naphthalene, benzyl-naphthyl ketone was obtained. This reduced by HI and P, and the product passed through an ignited tube gave a hydrocarbon identical with chrysene, having the formula $\begin{array}{l} C_{10}H_6-CH \\ | \qquad\quad \| \\ C_6H_4-CH \end{array}$.—*Ber. Berl. Chem. Ges.*, xii, 1078, June, 1879. G. F. B.

8. *Modern Chromatics, with applications to Art and Industry*; by OGDEN N. ROOD, Professor of Physics in Columbia College. 329 pp. 8vo. New York, 1879. (International Scientific Series—D. Appleton & Co.)—The very difficult task of presenting the principles of Optics so as to make them thoroughly intelligible to the reader has been admirably accomplished by Professor Rood in his work on Modern Chromatics. The work contains a discussion of the different ways by which colors are produced; the theory of color (that of Young); mixture of colors; complementary colors; and an account of the many effects produced by the combination and contrast of different colors. A closing chapter is devoted to the use of color in painting and decoration; it contains—what is indeed true of the whole work—much that will

be of high value to the artist, from one who has himself the great advantage of a practical knowledge of both drawing and painting. The book is largely made up of the results of the author's own investigations, which give it a character of its own; and it contains a large number of original illustrations.

9. *Color-blindness: its dangers and its detection;* by B. JOY JEFFRIES, A.M., M.D. 312 pp. 8vo. Boston, 1879. (Houghton, Osgood & Co.).—The subject of Color-blindness is one of not only very general interest, but of a high degree of practical importance, since many accidents on land and sea have resulted from misreading signals consequent on the imperfect vision of employés. The important work of Professor Holmgren published at Upsala, Sweden, in 1877, and soon afterward translated into French, first thoroughly developed this subject and made known its great importance. Dr. Jeffries has extended his investigations among the students of the various institutions of learning near Boston and Cambridge, embracing some 18,000 examinations, and the results are contained in this volume. It contains also a discussion of the whole subject, with particular instructions in regard to the use of Holmgren's method of testing for color-blindness. In his general conclusions, Dr. Jeffries states that;—one male in twenty-five is color-blind in a greater or less degree, though he may be himself unconscious of the defect; moreover, though sometimes caused temporarily or permanently by disease or injury, it is largely hereditary, and in that case is incurable. He also recommends that rigid and uniform proof of soundness of vision should be required of every employé in the railway or marine service.

10. *Friction and Lubrication: determinations of the laws and coefficients of friction by new methods and with new apparatus;* by R. H. THURSTON, A.M., C.E. 212 pp. 8vo. New York, 1879. —This work treats of the kinds of friction, and the different ways in which it arises in the use of machinery; also of the kinds of lubricants, and the methods of determining their value, with a full discussion of their composition. It also contains descriptions of new methods and apparatus, devised by the author, for the determination of the laws and coefficients of friction. The work will be of much value to the mechanical engineer.

11. *Neuere Apparate für Naturwissenschaftliche Schule und Forschung*, gesammelt von M. TH. EDELMANN. I. Lieferung, 96 pp. 8vo. Stuttgart, 1879 (Meyer & Zeller's Verlag).—This work is to be complete in three parts, of which the first is now issued. It contains descriptions of the newest and most complete apparatus, designed either for instruction in the lecture room, or for actual scientific investigations. The scope of the work is a wide one, and it will be found useful by physicists, chemists, physiologists, astronomers, and those working in many other branches of science. The descriptions are full and precise, and in many cases are accompanied by full-page illustrations which much increase the value of the work.

II. Geology and Mineralogy.

e *Auriferous Gravels of the Sierra Nevada of California;*). Whitney. Vol. vi, No. 1 (1st Part) of the Memoirs of seum of Comparative Zoology at Harvard College. 288 with colored maps and plates. Cambridge, 1879.—This belongs strictly to the series of Reports of the Geological of California, of which Professor Whitney was Director; he value and variety of its facts and discussions give reason inued regret that the Survey came so abruptly to its end the failure of the State to sustain it. Professor Whitney tinued since to some extent his investigations; and happily found in the Museum of Comparative Zoology at Harvard required for the publication of this new volume; and aid berally given, for the volume is brought out in the best ith several heliographic plates, and a number of colored ne of them a large sheet folded.

First Part presents first a sketch of the topography and Geology of the region of California, as a basis for the on of the main topic of the work—the Auriferous Gravels, ng necessary because these were made out of the earlier and owe their distribution and wonderful extent to the of the surface. The sketch is brief, yet clear and full, and, ring the many peculiarities in the mountains and strata country, and the masterly manner in which the facts are h, these pages have no less interest to the geologist than which follow. Only the more prominent peculiarities of ra Nevada are here cited.

ts singleness of mass, unlike the Coast Range and Appala- which consist of many prominent ridges.

s defined limits—a single broad valley, narrowing north- hat of the Sacramento and San Joaquin Rivers, bounding e west; but blending with the Coast Range on the north icinity of Mount Shasta, and bending westward into them f the parallel of 35° 30′.

ts steep slopes, generally 100 to 250 feet to the mile on the side, and 1,000 feet a mile for much of the eastern side.

ts profound gorges, like gashes in the steep sides, in which ams flow violently in seasons of great rains, though quiet in the much longer seasons of drought.

ts great height, numerous peaks exceeding 14,000 feet in above the sea-level, but none quite reaching 15,000 feet: atest height being between the parallels of 36° and 37° 30′.

Its granitic axis, widening southward, granite making the whole of its mass north of the Tahichipi Pass almost posa County, but north of this narrowing, and the schists ate, mica schist, chloritic and diabase schists, with some ine and limestone, mostly of Triassic and Jurassic age, and older than Carboniferous), constituting much of the range

on the west side; while north of American River they constitute nearly the whole width, only occasional areas of granite occurring along the crest and on the eastern slope; and little of the granite gneissoid.

(7) Its outflow of igneous rocks, which spread over the gravel deposits of much of the western slope in the several counties from Mariposa to Plumas, increase in extent in Butte and Plumas Counties, and cover nearly the whole of the surface north of Plumas from Lassen's Peak, a volcanic cone 10,500 feet high, on the northern boundary of this county, the Sierra being prolonged thence in a series of volcanic cones which culminates in Mount Shasta.

The Auriferous gravels exist over most of the western slope and are worked from Mariposa County into Plumas, or northward to the limit where the volcanic covering becomes general, and southward to that where granite is the chief rock. El Dorado, Placer and Nevada are the great mining counties. In the granitic regions of the Sierra the gravels are local in character, and, with small exceptions, not worked.

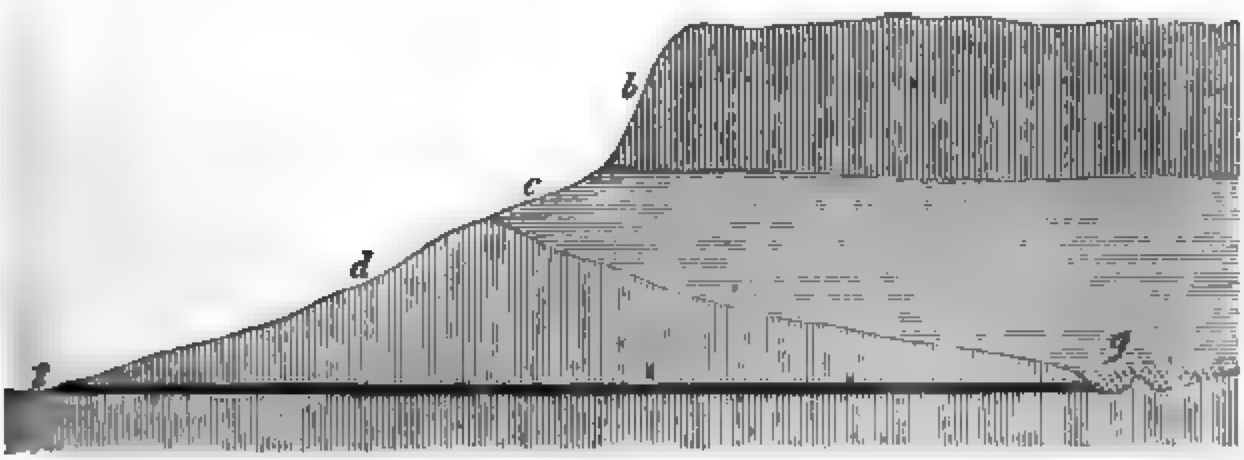
The schists, with their quartz veins, are the source of the gravel and its gold. Professor Whitney attributes the deposits to the action of the rivers of the later Tertiary and earlier time. He says, they "belong to a system of ancient rivers in the former beds of which detrital matter has been deposited, and which have since become in part obliterated by accumulations of lava, and extensively worn away by erosion." At present, the rivers and gorges are cut to a depth of many hundreds of feet below the surface either side. Starting from the foot-hills, the level of the surface between the streams rises much faster than the beds of the streams, so that when up 3,000 to 4,000 feet, the cuts are in many cases 1,000 to 2,000 feet deep. Further, there is a great difference between the level of the present beds and those of the era in which the gravels were deposited; this difference being 1,800 feet in the Middle Fork of American River at Michigan Bluff, 1,300 feet at Iowa Hill, on the divide south of the North Fork of the American. These cañons increase in depth to the north of the South Yuba: the difference of level between the Middle Fork of Feather River at Nelson's Point and the summit of the lava-bed of Pilot Peak which overlies the gravel being fully 3,650 feet; between the top of Mount Clermont, which is topped with gravel, and the valley at its base, 3,750 feet; between the top of Spanish Peak, which is capped with lava and gravel, and the valley of American River, 3,800 feet.

"An excellent idea of the topography of the hydraulic mining region is got by the traveler passing over the line of the Central Pacific Railroad, in descending the slope of the Sierra. After passing Blue Cañon, the slates begin to be met with, and all along below this, especially in the neighborhood of Dutch Flat, and beyond that for several miles, the road passes through a region of hydraulic mines, keeping on what seems to be a broad

plateau, which has an elevation of a little over 3,000 feet above the sea-level. Suddenly, just before reaching Colfax, a sharp bend in the line, at a place called Cape Horn, brings the road bed just on to the edge of the cañon of the North Fork of the American, down into and along which there is an unobstructed view for eight or ten miles, the bottom of the cañon being about 1,600 feet below the level of the road. The effect of the scene presented to the eye from this point is extremely striking, because the spectator has not been prepared, by anything which he has previously seen, to expect to find the flanks of the Sierra so deeply cut into by the streams, which seem of insignificant size as compared with the immense troughs at the bottom of which they run."

The course of the old channels are but partially made out. They are the objects of search by the miner, since the richer auriferous gravels lie along them, directly upon the bed rock. But although often of great depth and distinctness, they are only partially uncovered in the mining operations, and the facts are not examined and recorded when open to view, so that "we can never expect to know exactly what were the relations of the various parts of the old river system to one another." The lava-floods and beds of volcanic ashes and other material over the gravels prevent even the miner from exploring a large part of the old surface, though hydraulic mining and tunnelling have been pushed with great energy where it would pay. The volume gives a detailed account of observations on the gravel deposits and the bed-rock made for the Survey (on appointment of Professor Whitney) by Mr. W. A. Goodyear and Professor W. H. Pettee, which are illustrated by colored maps of the areas of lava and gravel.

Because of its special interest we copy here one of the sections of the Sonora, or Tuolumne County, Table Mountain, from Plate



F. It represents (on a scale of 300 feet to the inch) the cap or table-top of basalt (*b*) over 200 feet thick, overlying sand-beds and shaly material (*c*), with an auriferous gravel deposit (*g*) at the lowest part, and these resting on the nearly vertical metamorphic schists (*d*). The surface of the schists rises to the left, making there the "rim" of the old channel; and a tunnel (*t*) is represented passing through this rim to the gold-bearing gravels, a common method of search, though attended with large expense and not always successful.

A notice of the fossils of the gravels, including its Human relics, is deferred to another number.

2. *Richthofen's Theory of the Lœss, in the light of the Deposits of the Missouri;* by J. E. Todd, of Tabor, Iowa.—This memoir, read before the last meeting of the American Association, is a strong argument, well-sustained by facts drawn mainly from the region of the Missouri River, against the wind-drift theory of the lœss. The writer observes that although the mollusks are mainly terrestrial, "some semi-aquatic species, as *Succineas* and *Helicinas* are abundant from top to bottom [in the lœss of the Missouri], and the decidedly aquatic *Limnea humilis* is quite abundant in the Upper lœss of Western Iowa." Further, "the small size of the *Limneas* and absence of *Physas* in the latitude of Iowa, may be considered as indicating that the waters were cold, while the occurrence of numerous land-shells of species still inhabiting the region, indicates that the lands were more moist with their temperature not differing greatly from the present." Root-marks occur in much of the lœss but are mostly confined to its upper portion, being rare at a depth exceeding thirty or forty feet.

3. *Tertiary in Massachusetts Bay.*—Many fossiliferous bowlders have been found by Mr. Warren Upham, as reported by Mr. W. O. Crosby in the Proceedings of the Boston Natural History Society for February last, at different points in the Drift of Truro on Cape Cod. They include *Venericardia planicosta*, a Lower Eocene species of Virginia, and two others of the same genus, one probably *P. parva*, described by Lea, from Alabama, three species of Ostrea, one apparently *O. divaricata* Lea, of the Alabama Middle Eocene, an Anomia which is probably *A. tellinoides* Morton, a *Plicatula* near *P. filamentosa* Conrad, of the Alabama Eocene, besides several other species of shells, and remains of Echinoderms and a Galaxea-like coral. Mr. Crosby concludes that the Tertiary formation, which was the source of these fossils, now forms the floor of Massachusetts Bay somewhere to the northward of Cape Cod. These facts derive additional interest from a comparison with those announced by Professor Verrill, in the number of this Journal for October last, with regard to submarine Tertiary along George's Bank and Grand Bank. The species found are wholly different.

4. *Report of Progress in the Juniata District on the Fossil Iron Ore-beds of Middle Pennsylvania*, by John H. Dewees; with a *Report on the Aughwick Valley and East Broad Top District*, by C. A. Ashburner. Second Pennsylvania Geological Survey. Harrisburg, 1878.—This Report is noticed by title only on page 262 of the last volume of this Journal. It opens with a Preface by Prof. Lesley, Director of the Survey, giving a general sketch of the formations in which iron-bearing beds occur, the most important of which are those of the Clinton group, and the Marcellus. Mr. Dewees presents the facts with full details of the stratification. Excellent sections of the folded rocks are given

hich are by Mr. Ashburner, and are continued in his portion of ıe volume; and these are supplemented by large and fine col-·ed sections and maps in a portfolio. This geologist, moreover, escribes the Silurian and Devonian rocks from the Trenton to ıe Hamilton in the valley of the Juniata, from Lewistown in ifflin County to Mount Union in Huntingdon County; and the ccount has special interest since it illustrates the typical struc-ıre of Central Pennsylvania. A carefully measured section from ıe bottom of the Trenton to the top of the Mahoning Sandstone, · top of the Lower Productive Coal measures, shows a thickness ' 18,397 feet—and in this long section, 68·9 feet is the average ıickness for the 267 separate strata included. A catalogue of ɔecimens, and another of heights above the sea-level are given, ı an Appendix to the Report. The former is on a plan worthy ' imitation. Mr. Ashburner places on the labels of his speci-ens (besides the geographical position) the number of the stra-ım, the distance in feet from the lower limit of the same, and so the dip of the beds; so that any future investigator will be ɔle to take up any part of the work for revision or for further udy.

5. *On the Geology of Gibraltar.*—The following facts are om a paper by Professor A. C. Ramsay and James Geikie, in ıe Quarterly Journal of the Geological Society for August, 1878. -More than three-fourths of the promontory of Gibraltar consists ' a grayish white bedded limestone, containing occasional ısts of Rhynchonellæ and encrinal stems, the former closely like '. *concinna*, a species abundant in the Cornbrash and Coral Rag. he limestone is overlaid by shales of various shades of color, ith some thin calcareous beds, which have afforded no fossils. he dip of the rocks is in general over 40°, and in some parts 75° ıd higher. Upon these beds there are superficial deposits. The dest is a limestone breccia, covering a large area in the district ' Buena Vista and Rosia, and in the vicinity of the South arracks; it is unfossiliferous. The authors attribute the origin ' the limestone fragments of which the breccia consists to the osts or cold of the Glacial era. The mean temperature of the ɔldest month (February) is now 54·2°, and the lowest point ached in the six years from 1853 to 1859 was 32·7°; and no ebris is now forming from such a cause or any other. Besides ıese surface breccias or conglomerates there are also bone-breccias ı caves and fissures. The famous bone-breccia at Rosia Bay ccupies a vertical fissure of erosion in the above-described sur-ce breccia, while the Genista breccia occurs in a true cave.

The promontory bears evidence of different sea-levels in terraces · platforms cut in the solid rock, surmounted sometimes by cal-reous sandstones. The Europa Flats is one of these sea-levels ı the southern portion of the promontory; it extends from west east for 1650 feet, and it averages 115 feet above the sea-level, ough sloping up from 90 feet to 150 feet. It appears also at her points. The calcareous conglomerate over it contains some

remains of Mediterranean species and is evidently of marine shore origin. Another such terrace has a height not less than 250 feet; a third, about 830 yards in length and over 330 broad, is 370 feet above the sea. In the front of the same cliffs at a height of 170 feet an oyster-bed was formerly visible.

Among the species of Mammals identified by Messrs. Busk and Falconer from the Genista cave, there are *Rhinoceros hemitœchus*, *Horse*, *Boar*, *Cervus elaphas*, *C. dama*, *Ibex*, *Bear*, *Wolf*, *Hyæna crocuta*, *Lion*, *Panther*, *Lynx*, etc., and these authors concluded that, at the time these animals were living, Europe and Africa were at some point united across the Mediterranean. With this in view, the succession of Quaternary events in Gibraltar is given as follows:

(1.) *Great unfossiliferous limestone-agglomerate of Buena Vista, etc.*—Land of greater extent than now; winters very cold; Gibraltar apparently not tenanted by the Quaternary Mammalia.

(2.) *Caves and fissures with bone-breccia.*—Land of greater extent than now; Europe and Africa united; climate genial; immigration of the African Mammalia.

(3.) *Platforms or terraces of marine erosion (in part), calcareous sands, etc.*—Depression of the land to the extent of 700 feet below present level; movement interrupted by pauses of longer or shorter duration; climate apparently much the same as now.

(4.) *Platforms of marine erosion (in part); Alameda Sands; formation of sand-slopes on east coast, as at Monkey's Cave; mammalian remains under beach or later limestone-agglomerate (perhaps cave-deposits in part).*—Reëlevation; land of greater extent than now (Africa and Europe perhaps reunited); climate probably genial.

(5.) *Later limestone-agglomerates resting upon and obscuring erosion-terraces and sand-slopes, etc.*—Geographical conditions probably same as during part of 4; winter considerably more severe than now.

(6.) *The present.*—Characterized by the absence of the action of frost.

On the conclusion of the reading of the paper, the statement was made by Admiral Spratt, that to the westward of Farifa Point a submarine ridge exists which nowhere exceeds 130 fathoms in depth; so that an upheaval of about 800 feet would connect the two continents by dry land.

6. *Etudes Synthétiques de Géologie Expérimental*, par A. Daubrée, Membre de L'Institut, Inspecteur Général des Mines, etc. Première Partie, *Application de la Méthode Expérimentale a l'étude de divers Phénomènes Géologiques.* 478 pp. 8vo. Paris, 1879. (Dunod).—The admirable researches in Experimental Geology of Professor Daubrée have in part been briefly announced in former volumes of this Journal. The work just issued under the above title contains these results in full, and, in addition, those

of more recent researches. After a historical introduction, the author gives an account of his observations illustrating the history of metalliferous deposits, and especially those of tin, lead and platinum, bringing in a wide range of facts relating to such deposits, and among them prominently his remarkable discoveries of a large number of ores of modern formation made out of a lot of Roman coins at the Warm Springs of Bourbonne-les-Bains, and also of similar formations at some other localities; and, after stating the facts, the chemistry of the phenomena and the geological inferences from the facts are learnedly presented.

Professor Daubrée's next subject is Experimental illustrations of the origin of metamorphic and eruptive rocks. Under this head numerous observations are reviewed, and in addition the results of his own experiments, with regard to the formation of silicates by means of superheated water: such as the transformation of glass into a hydrated silica and crystallized quartz, the glass sometimes containing minute well-formed crystals of pyroxene (figures of which crystals as well as of those of quartz are given); and the formation of zeolites (chabazite, apophyllite, etc.) at Plombières, and at other warm baths inside of bricks, along with opal, chalcedony, tridymite, aragonite, and other species. Volcanic phenomena are next illustrated by experiments, and with this chapter the first section of the volume closes. The second section is occupied with mechanical problems: (1) the making of sand-beds and clay-beds, showing for example, the effects of the trituration of feldspar in water (some loss of alkali taking place in pure water and "incomparably less" with salt water), in carbonated waters, etc.; (2) the scratching and polishing of rocks, their flexures, fractures, faults, jointed structure, slaty cleavage and schistosity, and the distortions of fossils and pebbles; and (3) the production of heat in rocks by mechanical methods. All the modes of experimenting are described in detail, and illustrated by figures; many of the results obtained in his mechanical processes are also figured, and their bearings on geological problems are fully and ably discussed. The work is thus in every part a rich contribution to the science of geology; moreover it is made highly attractive by its style of publication and the beauty of its illustrations.

7. *Rocks under London.*—In the Artesian boring in the Tottenham Court Road, according to a paper by Professor Prestwich (Quart. J. Geol. Soc., Nov., 1878), it was found that the Chalk had a total thickness of 652½ feet, the Upper Greensand 28 feet, the Gault 160 feet. Below this was a bed three to four feet thick of phosphatic nodules and quartz pebbles; and then a calcareous stratum, more or less sandy, and part of it oolitic, sixty-four feet thick, which was shown by its fossils to represent the Lower Greensand. Underneath, at a depth of 1064 feet, the bore-hole entered mottled red, purple and greenish shales, to some extent calcareous, having a dip of 35°, and these continued for eighty-five feet; they afforded the fossils *Spirifer disjuncta*, *Rhynchonella cuboides*, and other Devonian species. The rocks

resemble those of Pernes, near Bethune, where the chalk rests on the upturned Devonian. Professor Prestwich attributes the calcareous character of the Lower Greensand to the Paleozoic limestones on which it rests.

8. *Fossils of the Utica Slate and Metamorphoses of Triarthrus Becki*, by C. D. WALCOTT. Trans. Albany Institute, June, 1879. —Mr. Walcott, after remarks on the Hudson River Group, describes, from the Utica Slate, three new species of Fucoids, five of Graptolites, *Modiolopsis cancellata* and *Orthoceras Oneidaense;* and then gives, with much detail, an account of the synonymy and metamorphoses of *Triarthrus Becki* which is illustrated by sixteen figures. The smallest individual of the species described and figured has only one thoracic segment and a length of but 1·125 mm., and the largest a length of 53 mm. In the former the pygidium is very nearly as long as the head segment, and in the latter it is one-third as long. The memoir closes with a table of Utica slate fossils showing their stratigraphical range.

9. *New Calciferous fossils from Saratoga County, New York.* —Mr. C. D. Walcott has described as new the following species: *Platyceras minutissimum*, *Metoptoma cornutiforme ; Conocephalites calciferus*, *C. Hartii*, *Ptychaspis speciosus.* *Bathyurus armatus* of Billings (from the Quebec group), or a form closely related, also occurs in the beds.—32*nd Ann. Rep. N. Y. Mus. Nat. Hist.*

10. *Fossil wood related to Cypress from Calistoga, California.* —H. Conwentz, of Breslau, has published in the Jahrbuch für Mineralogie, etc., for 1878, a description, with microscopic sections, of a fossil wood from Calistoga, which he has named *Cupressinoxylon taxodioides.*

11. *Erdbeben-Studien* von R. HŒRNES.—After a general discussion of earthquake phenomena, Hœrnes describes in detail the earthquake of Belluno, of June 29, 1873, that of Klana (near Trieste) of March, 1870, and also that of Villach in 1348. The conclusions which are finally reached are stated as follows: (1) Shakings of the earth are produced by various causes: sometimes, though rarely, by the tumbling in of subterranean caves; also, though only locally, by volcanic force; but the true earthquakes, those of most frequent occurrence and greatest extent, are a direct consequence of mountain formation. (2) On the inner side of a great mountain chain, earthquakes take place along peripheral lines of fracture which are shown by the progression of the points of shock. These disturbances seem to be produced by the sinking of the inner zones to true fault-fractures. (3) Besides the peripheral zones of shaking, there exist on the inner edge of the chain, radial lines, coinciding with cross-fractures on which severe earthquakes often occur. These radial lines very probably are to be regarded in part as the boundaries of masses occasionally involved in sinking, and in part also as the line of separation of two regions undergoing a horizontal movement. (4) Between the peripheral and radial lines no sharp limit can be drawn, since the

boundary of a region of depression is very irregular; moreover the continuation of the cross-fracture not unfrequently coincides with the longitudinal fractures, and *vice versa.* (5) The connection of the seismical lines of different dynamical value is most readily explained by the assumption that a portion of the earth's crust gives its motion to another, and this makes itself felt by the shakings along the course of a fracture.—*Jahrb. k. k. geol. Reichsanstalt*, xxviii, p. 387, 1878. E. S. D.

12. *Examination of the North Carolina Uranium minerals;* by F. A. GENTH (American Chemical Journal, vol. i, p. 87).—The uranium minerals of North Carolina were first described by Professor W. C. Kerr (this Journal, III, xiv, 496, Dec., 1877). As stated by him, they occur as irregular nodules and rounded masses in the mica-bearing portion of a large granite vein; the locality is called the Flat Rock mine. Dr. Genth has subjected the minerals to a thorough chemical examination, and in the main confirmed the determination of the species made by Professor Kerr. The masses contain, in many cases, a nucleus of uraninite; surrounding this is an orange-colored mineral, gummite; and interpenetrating it and forming a crust over it, a light yellow mineral, identified by Dr. Genth as uranotil. The uraninite occurred in too small a quantity to allow of its being analyzed. The *gummite* has a compact, amorphous structure; reddish-yellow to deep orange-red color; and subconchoidal to uneven fracture; with hardness = 3; and specific gravity = 4·840. The mean of three analyses gave:—

UO_3	AlO_3	PbO	BaO, SrO	CaO	SiO_2	P_2O_5	H_2O
75·20	0·53	5·57	1·08	2·05	4·63	0·12	10·54=99·72.

Dr. Genth regards the gummite as a mechanical mixture of:—

Uranium hydrate	$= H_2(UO_2)O_2 + H_2O$	=	40·10 p. c.
Uranotil	$= Ca_3(UO_2)_6Si_6O_{21} + 18H_2O$	=	33·38 p. c.
Lead uranate	$= Pb(UO_2)_2O_3 + 6H_2O$	=	22·66 p. c.
Barium uranate	$= Ba(UO_2)_2O_3 + 6H_2O$	=	4·26 p. c.
			100·40.

The pale yellow coating surrounding the gummite has been identified by Dr. Genth as *uranotil*, a mineral originally described by Boricky from Wölsendorf, Bavaria. As occurring in North Carolina it is amorphous, compact; hardness = 2·5; specific gravity 3·834; color pale straw-yellow to lemon-yellow; luster waxy to dull. The mean of two analyses gave:—

SiO_2	$AlO_3(FlO_3)$	UO_3	PbO	BaO	SrO	CaO	P_2O_5	H_2O
13·75	tr.	66·67	0·60	0·28	0·13	6·67	0·29	12·02=99·43

For this the formula $Ca_3(UO_2)_6Si_6O_{21} + 18H_2O$ is suggested, which requires: SiO_2 13·95, UO_3 66·98, CaO 6·51, H_2O 12·56 = 100·00.

In addition to the above, autunite has been found at the locality and, associated closely with it, a new species called by the describer *phosphuranylite.* It occurs as a pulverulent incrustation on quartz, feldspar and mica. Under the microscope very minute rectangular scales with pearly luster were distinguished.

Color deep lemon-yellow. An analysis gave: P_2O_5 11·30, UO_3 71·73, PbO 4·40, H_2O 10·48 = 97·91. The lead is regarded as being present as cerussite; if this is deducted the result becomes: P_2O_5 12·08, UO_3 76·71, H_2O 11·21 = 100. The formula obtained is $(UO_2)_3P_2O_8 + 6H_2O$, which requires: P_2O_5 12·75, UO_3 77·56, H_2O 9·69 = 100. E. S. D.

III. Botany and Zoology.

1. *Report upon U. S. Geographical Surveys west of the 100th Meridian, in charge of First Lieut.* Geo. M. Wheeler, Corps of Engineers, U. S. A., etc. Vol. VI, *Botany;* by J. T. Rothrock, etc. 1878.—We have been prevented from giving an earlier notice of this fine volume, and want of space now imperatively restricts us to narrow limits. We have not neglected it, however, in the manner that the date on the title page would seem to indicate. The title gives the year 1878, but the volume, passing slowly through the press, was completed and issued in May, 1879, and it should bear that date. The collections reported on were made during the years 1871 and 1875 inclusive, in Nevada, Utah, Colorado, New Mexico and Arizona; also in the southern part of California. But the Californian portion of this report is reduced to a catalogue in an appendix. It furnishes, however, one of the most interesting of the figures, that of the curious Lobeliaceous genus *Palmarella.* As no reference is made to the fact in the letter-press, which is restricted to a mere explanation of the plate, it is due to Professor Rothrock to state that he was, we believe, the original discoverer of the plant, having collected it sometime before Dr. Palmer found it on the borders of Lower California. But the specimens were not communicated to us, nor in any way made known, until after those of Dr. Palmer had been received and described.

This volume contains 414 pages, 4to, and 30 plates, besides a striking frontispiece-plate in color, giving a view of a "grove" (if it may be so called) of the giant Cactus, *Cereus giganteus.* This, again, finds no mention in the Catalogue, but is referred to in the general report. This general report, of fifty pages, is a most interesting and important portion of the volume. From it, if space and time allowed, we should make ample extracts; for it deals with attractive and practical questions in a graphic and taking way. There is first, a sketch of the Colorado District, its character, climate and phytological features, also its agricultural resources and its timber. Then, of New Mexico and the Arizona District, which is scientifically treated in a similar practical way; and a third chapter consists of notes on the economic botany of the region, in which particular attention is paid to the medicinal and supposed medicinal plants.

Chapter IV, or the remainder of the volume, entitled Catalogue of the Plants collected, is the systematic portion of the report; and for this Sereno Watson's Botany of Clarence King's Survey of the 40th parallel is the worthy model. Particular orders are

ked up by special collaborators; as, the *Leguminosæ* by Wat- the *Cactaceæ* by Engelmann, who has also contributed other iis favorite orders, *Asclepiadeæ*, *Gentianaceæ*, *Euphorbiaceæ*, *uliferæ*, *Loranthaceæ* and *Coniferæ*; while Professor Porter done the *Scrophulariaceæ*, *Labiatæ*, *Polemoniaceæ*, *Polygona-* etc.; Dr. Vasey, the Grasses, Professor Eaton, the Ferns, which conspicuously distinguished by a typography at variance with rest of the volume; Mr. James, the Mosses; Mr. Austin, the aticæ (a bare list); and Professor Tuckerman, the Lichens.
he plates which illustrate this part of the work, thirty in iber, are mostly from Isaac Sprague's drawings, are on the le well chosen, and are capitally engraved on stone. The t interesting of these may be enumerated. *Canotia hola-* *ha*, admirably represented, heads the list, *Parryella filifolia* so by Sprague, but *Petalonyx nitidus* is not so. *Leucampyx* *berryi*, *Chætadelpha Wheeleri*, *Nama Rothrockii*, and *Pal-* *ella debilis* are also particularly noteworthy. The latter has i already referred to. Of Cryptogams, there is only *Notholæna* *keri* of Eaton. While this work was in progress, Dr. Roth- : was called to the chair of Botany in the University of nsylvania, at Philadelphia, where he has done much and most ptable work in building up the department, under conditions ome respects discouraging, but with excellent results. It ands great energy and perseverance to carry on such work at the same time to bring out a volume like this. A. G.

The Flora of British India.—Part VI carries the second ime of this standard work from the *Myrtaceæ* (by Duthie) to *Araliaceæ*, and most of the orders are elaborated by C. B. ·ke. The Himalayan *Osmorrhiza* is named *O. Claytoni* and species made to include *O. longistylis* and *O. brevistylis;* which orth America are quite distinct. A. G.

Refugium Botanicum. London, Van Vorst.—This work, so rally planned by Mr. Wilson Saunders, was left with a hiatus, ' the first fascicle of the second volume (devoted to Orchids edited by Reichenbach, having appeared. There is now a nd part, bearing the date of 1878; but each leaf of the letter- s bears the date of October, 1872, and a concluding part is nised. The Orchids illustrated are all tropical. A. G.

Transactions and Proceedings of the Botanical Society of *nburgh*, vol. xiii, part 2. 1878.—The more interesting articles his volume are: 1, Professor Balfour's notes of a Continental , in 1877, being an account of the celebration of the 400th versary of the foundation of the Upsala University, to which vas a delegate, the description and history of the Botanic den and other appliances for botanical instruction in that versity, followed by a similar account of the gardens and aria of Stockholm and Lund; also those of Copenhagen, , Hamburgh, Berlin, Leyden and Brussels; 2, Sir Robert stison's capital essay, On the exact measurement of Trees, and pplications; 3, Dr. Bayley Balfour's elaborate and noteworthy r, On the genus *Halophila*, with 5 plates. A. G.

5. *The Journal of the Linnean Society: Botany*, vol. xvii.—Four parts of this volume have appeared, the latest (no. 101) in May, 1879. The more notable articles are the following.

Experiments on the Nutrition of Drosera rotundifolia, by Francis Darwin. The conclusions reached have become familiar through abstracts published at the time of the experiments. The paper is prefaced by a summary of the various and most diverse opinions of naturalists upon the question whether the leaves of *Drosera* and *Dionæa* can absorb animal matter, and whether, if they do, any advantage to the plant results. The affirmative is clearly made out by well-devised experiment; yet, "it may be pointed out that this advantage of the fed *Drosera* plants is one which would escape the notice of a casual observer." A postscript refers to the full confirmation of his results by the researches of Reess, Kellermann and Raumer, published in the Botanische Zeitung.

Observations on the Genus Pandanus (the Screw-Pines), by Dr. Isaac Bayley Balfour. This paper is prefatory to a full monograph of *Pandaneæ*, which this most promising botanist has undertaken, after a study of several of its representatives in a living state and in their habitats. We may hope that his timely call to the botanical chair at the University of Glasgow will bring increased facilities for this kind of work. Professor Balfour (fil.) has examined at Paris the materials on which Gaudichaud founded thirteen new genera, and he reduces them all to *Pandanus*, along with two genera added by DeVriese.

Notes on the Mahwa Tree (*Bassia latifolia*), by E. Lockwood. A tree of India, largely planted in Bengal, and which "may be called a fountain yielding food, wine and oil, to the inhabitants of the country in which it grows." It is the corolla of this tree which is eaten as food and from which a spirit is distilled. Each tree yields two or three hundred weight of corollas, of which a vast quantity goes to feed the forest birds and beasts, also to supply a nourishing food to the poorer classes; and from a hundred weight of Mahwa six gallons of proof spirit can be produced. The fruit, which follows after the corollas have fallen, yields seeds from which a greenish yellow oil is expressed.

A Synopsis of Hypoxidaceæ, by J. G. Baker. Of *Hypoxys* fifty-one species are characterized: the three related genera give a dozen more.

Observations on Hemileia vastatrix, the so-called Coffee-leaf Disease, by the Rev. R. Abbay. With two plates, containing five illustrations of the coffee-fungus.

Notes on Euphorbiaceæ, by George Bentham. An account of this important paper, especially of the part of it which treats certain points in nomenclature, has already appeared in this Journal.

Notes on Cleistogamic Flowers, chiefly of *Viola*, *Oxalis*, and *Impatiens*, by A. W. Bennett. A clear exposition, illustrated by wood-cut figures. The first is from our North American *Viola cucullata*, in which the cleistogamous blossoms are unusually

large and very favorable for observation. Their hollow style with large orifice is delineated, showing that an open tube extends to the cavity of the ovary. But Mr. Bennett has not been able to detect the entrance of a single pollen-tube into the ovary through this open passage, and indeed he suspects that they penetrate the tissue of the style. Observations should be made here upon the native plant; and we commend the investigation to some of our botanists who may like to try their hand at microscopic investigation. They will find it interesting to observe that wonderful phenomena, the growth and prolongation of the pollen-tubes from the anther to the stigma through a considerable distance in a straight line, with unerring certainty, as if guided by some unseen agency in the right direction.

On the Absorption of Rain and Dew by the green parts of Plants; by the Rev. George Henslow. Along with Boussingault's contemporary researches, these experiments appear to settle the question against the conclusions of Duchartre, who confidently decided that foliage could not absorb water or aqueous vapor. The gardeners could never believe this, and it is now clear that leaves and other green parts may imbibe moisture and do so evidently under favorable circumstances.

Note on the Genus Oudneya Brown, by Dr. Henry Trimen. The accidental discovery of Dr. Oudney's herbarium, which Brown had tucked away, has brought to light the plant upon which Robert Brown founded this genus. It proves to be the *Henophyton deserti*, as the authors of the Genera Plantarum had indeed surmised, though they had sought in vain for the original. A nice question in nomenclature now arises. Brown unqualifiedly calls his plant the *Hesperis nitens* of Viviani. Cosson and Durieu, trusting to this, and ascertaining that the plant in their hands is not Viviani's *Hesperis*, confidently concluded that it could not be Oudneya, and so established, upon its true characters, the genus *Henonia* or *Henophyton.* Hooker and Bentham adopt the genus, guessing that it may be Brown's *Oudneya*, a conclusion to which Brown's character would never lead them. For the latter, not having mature seed, makes of it an Arabideous genus, instead of a Brassicaceous. Shall the rightly characterized genus now be superseded by the imperfectly and by implication erroneously described genus, which was also confused with something else? Dr. Trimen implicitly assumes that it should. If Brown had been a botanist of less fame and less accuracy, the current name (*Henophyton*) would probably remain undisturbed. The question may be settled by enquiring what course the authors of the Genera Plantarum would have pursued if they had identified Brown's genus by finding his specimen. We suppose they would have adopted the older name of *Oudneya;* and if so, it may claim to be adopted now. A. G.

6. *Floral Dissections illustrative of the typical Genera of the British Natural Orders, Lithographed by the* Rev. George Henslow, Lecturer on Botany at St. Bartholomew's Hospital, &c.

For the use of Schools and Students in Botany. London: E. Stanford.—An oblong 4to, with 20 pages of letter-press and 8 plates crowded with well-chosen analyses, of rather small size, between one and two hundred on each plate. The price is not mentioned, and is probably low; the execution of the figures is fairly good, and the letter-press explaining them is also a model of condensation. The book may be recommended to students and classes in the United States. A. G.

7. *Decease of Botanists.*—The mortality among botanists during the first half of the year 1879 is remarkable. Among the deceased are the venerable *Reichenbach*, *Itzigsohn*, *Angström*, *Bueck* (who made the Candollean index), *Wm. Schimper* (the schoolmate of Agassiz and one of the first investigators of phyllotaxy, but who passed most of his life in Abysinia), *Grisebach*, *Karl Koch*, *Moore* of Glasnevin, besides our own *Bigelow* and *Robbins*. A. G.

8. Psyche: *Anatomy of* Amblychila cylindriformis *Say*, by C. F. Gissler. This carefully prepared memoir is published in volume II of Psyche, the number for May–June, 1879. It is illustrated by one plate, well executed on stone by the author.

IV. Miscellaneous Scientific Intelligence.

1. *Preliminary Note on the Substances which produce the Chromospheric Lines;* by J. Norman Lockyer, F.R.S.—Hitherto, when observations have been made of the lines visible in the sun's chromosphere, by means of the method introduced by Janssen and myself in 1868, the idea has been that we witness in solar storms the ejection of vapors of metallic elements with which we are familiar from the photosphere.

A preliminary discussion of the vast store of observations recorded by the Italian astronomers (chief among them Professor Tacchini), Professor Young and myself, has shown me that this view is in all probability unsound. The lines observed are in almost all cases what I have elsewhere termed and described as *basic lines;* of these I only need for the present refer to the following:—

b_3 ascribed by Ångström and Kirchoff to iron and nickel.
b_4 " Ångström to magnesium and iron.
5268 by Ångström to cobalt and iron.
5269 " " calcium and iron.
5235 " " cobalt and iron.
5017 " " nickel.
4215 " " calcium, but to strontium by myself.
5416 an unnamed line.

Hence, following out the reasoning employed in my previous paper, the bright lines in the solar chromosphere are chiefly lines due to the not yet isolated bases of the so-called elements, and the solar phenomena in their totality are in all probability due to dissociation at the photospheric level, and association at higher levels. In this way the vertical currents in the solar atmosphere,

both ascending and descending, intense absorption in sun-spots, their association with the faculæ, and the apparently continuous spectrum of the corona and its structure, find an easy solution.

We are yet as far as ever from a demonstration of the cause of the variation in the temperature of the sun; but the excess of so-called calcium with minimum sun-spots, and excess of so-called hydrogen with maximum sun-spots follow naturally from the hypothesis, and afford indications that the temperature of the hottest region in the sun closely approximates to that of the reversing layer in stars of the type of Sirius and α Lyræ.

If it be conceded that the existence of these lines in the chromosphere indicates the existence of basic molecules in the sun, it follows that as these lines are also seen generally in the spectra of two different metals in the electric arc, we must be dealing with the bases in the arc also.

2. *An Arabic Scientific Journal.*—The first number of a Scientific Monthly Journal in Arabic, has been recently issued at Beirût, in Syria. It is published by Sh. Makarius & Company of that city.

3. *Bulletino del Vulcanismo Italiano;* Professor M. S. di Rossi. Roma, 1878.—A few years ago Cav. Michele Rossi determined to attempt the collection and monthly publication of facts connected with Italian Vulcanology. The experiment succeeded, and a volume of 140 pages has been issued recording all the phenomena of internal telluric dynamics observed in Italy and Sicily during 1878. A list is given of twenty-six Italian observatories where seismic observations are recorded, and whose observers are in communication with Professor di Rossi. Among minor notices we find mention of various new seismological observatories, including that of the Solfatara at Pazzuoli, and of the earthquake which was felt at Fiulmalbo, Florence, and Rocca di Papa. There are letters on the application of the microphone to seismological studies, from Professor di Rossi and Count G. Mocenigo; and the Umbrian earthquake of September, 1878, is described by Professor A. Ricci. Silvestri gives an account of the mud eruption which broke out on the sides of Etna near Paterno in December; and Palmieri continues his "Cronaca Vesuviana" to the end of September, 1878. An exact account of the time of occurrence of earthquake phenomena in any part of Italy is entered in a tabular form, and it is surprising to notice that not a day passes in Italy without some indication of endogenous dynamic action. At the end of the volume is a large diagram showing at a glance the daily distribution of earthquakes throughout Italy.

But the most interesting article in the Bulletino is that on the *application of the microphone to the study of subterraneous meteorology*, by Professor Michele di Rossi. In 1875 Count Mocenigo, of Vicenza, made an observation which was nothing less than the fundamental fact of the microphone. He observed that electric currents indicate in a galvanometer perturbations

and interruptions by means of frictions and shocks produced artificially between conductors not in perfect contact. He also observed that the same phenomena were produced by natural and unknown causes, when the apparatus had not received any artificial shock. From the account of his observations Professor di Rossi concludes that these unknown perturbations arose from microseismic oscillations of the soil. He communicated his views to Count Mocenigo, who at once commenced experimenting in the direction indicated, when the news of the invention of the microphone in America was received. Professor di Rossi then commenced a series of experiments with the microphone in the Seismic Observatory which he has established at Rocca di Papa, seventeen miles from Rome. A special microphone, consisting of a balanced pointed lever lightly touching a plate of silver, was mounted on a stone pedestal and was placed twenty meters under ground, at a distance from habitations and from roads. It was also thoroughly isolated, and shut up in a box filled with wool. The instrument was watched during some of the stillest hours of the night, and the same mysterious sounds which Count Mocenigo had recognized were heard by di Rossi, which he considers were incontestably natural and intratelluric. The microseismic sounds were speedily differentiated from other sounds, and their nature was completely confirmed by their frequent coincidence with motions of the seismograph. On one occasion, as di Rossi was listening at about half past three o'clock in the morning, the telephone connected with his subterranean microphone emitted sounds like the discharge of musketry, of such loudness that he feared they would awaken a child who slept in the same room, and he therefore disconnected the telephone. A short time afterward, toward four o'clock, a sensible shock of earthquake occurred, for which the sounds had been the microphonic preparation. The microphone was afterward transported to the observatory on Vesuvius, and it was then possible to trace the precise correspondence between the movements of the seismograph and the sounds of the microphone. The above is condensed from G. F. Rodwell, Nature, vol. xx, p. 179.

In this connection it may be remarked that the sources of the seismic vibrations which become audible through the microphone may be various. Thus, they might be produced by:

(1.) The explosion of bubbles made by the escaping vapors, which in the case of viscid lavas would require considerable internal pressure before rupture.

(2.) The sudden production or condensation of vapors.

(3.) The more general condition of stress produced in the earth's crust, resulting in more or less yielding along lines of least resistance.

The premonitory sounds heard in the microphone may with probability be referred to the first or second class. C. G. R.

THE

AMERICAN

JRNAL OF SCIENCE AND ARTS.

[THIRD SERIES.]

XXVI.—*The Pertinacity and Predominance of Weeds*; by ASA GRAY.

VEED is defined by the dictionaries to be "Any useless ublesome plant." "Every plant which grows in a field than that of which the seed has been [intentionally] sown e husbandman is a weed," says the Penny Cyclopædia, ed in Worcester's Dictionary. The Treasury of Botany s it as "Any plant which obtrusively occupies cultivated ssed ground, to the exclusion or injury of some particular ntended to be grown. Thus, even the most useful plants become weeds if they appear out of their proper place. erm is sometimes applied to any insignificant-looking or fitable plants which grow profusely in a state of nature; o any noxious or useless plant." We may for present ses consider weeds to be plants which tend to take preva- ossession of soil used for man's purposes, irrespective of ill; and, in accordance with usage, we may restrict the to herbs. This excludes predominant indigenous plants ying ground in a state of nature. Such become weeds they conspicuously intrude into cultivated fields, meadows, res, or the ground around dwellings. Many are unat- re, but not a few are ornamental; many are injurious, me are truly useful. White Clover is an instance of the Bur Clover (*Medicago denticulata*) is in California very ble as food for cattle and sheep, and very injurious by amage which the burs cause to wool. In the United , and perhaps in most parts of the world, a large majority e weeds are introduced plants, brought into the country

directly or indirectly by man. Some—such as Dandelion, Yarrow, and probably the common Plantain and the common Purslane—are importations as weeds, although the species naturally occupy some part of the country.

Why weeds are so pertinacious and aggressive, is too large and loose a question: for any herb whatever when successfully aggressive becomes a weed; and the reasons of predominance may be almost as diverse as the weeds themselves. But we may enquire, whether weeds have any common characteristic which may give them advantage, and why the greater part of the weeds of the United States, and probably of similar temperate countries, should be foreigners.

As to the second question, this is strikingly the case throughout the Atlantic side of temperate North America, in which the weeds have mainly come from Europe; but it is not so, or hardly so, west of the Mississippi in the region of prairies and plains. So that the answer we are accustomed to give must be to a great extent the true one, namely, that, as the district here in which weeds from the Old World prevail was naturally forest-clad, there were few of its native herbs which, if they could bear the exposure at all, were capable of competition on cleared land with emigrants from the Old World. It may be said that these same European weeds, here prepotent, had survived and adapted themselves to the change from forest to cleared land in Europe, and therefore our forest-bred herbs might have done the same thing here. But in the first place the change must have been far more sudden here than in Europe; and in the next place, we suppose that most of the herbs in question never were indigenous to the originally forest-covered regions of the Old World; but rather, as western and northern Europe became agricultural and pastoral, these plants came with the husbandmen and the flocks, or followed them, from the woodless or sparsely wooded regions farther east where they originated. This, however, will not hold for some of them, such as Dandelion, Yarrow, and Ox-eye Daisy. It may be said that our weeds might have come to a considerable extent from the bordering more open districts on the west and south. But there was little opportunity until recently, as the settlement of the country began on the eastern border; yet a certain number of our weeds appear to have been thus derived: for instance, *Mollugo verticillata*, *Erigeron Canadense*, *Xanthium*, *Ambrosia artemisiæfolia*, *Verbena hastata*, *V. urticifolia*, etc., *Veronica peregrina*, *Solanum Carolinense*, various species of *Amarantus* and *Euphorbia*, *Panicum capillare*, etc. Of late, and in consequence of increased communication with the Mississippi region and beyond—especially by rail-roads—other plants are coming in to the Eastern States as weeds, step by step, by

somewhat rapid strides; such as *Dysodia chrysanthemoides, Matricaria discoidea, Artemisia biennis.* Fifty years ago *Rudbeckia hirta*, which flourished from the Alleghanies westward, was unknown farther east. Now, since twenty years, it is an abundant and conspicuous weed in grass-fields throughout the Eastern States, having been accidentally disseminated with Red-clover seed from the Western States.

There are also native American weeds, doubtless indigenous to the region, such as *Asclepias Cornuti*, *Antennaria margaritacea* and *A. plantaginifolia*, and in enriched soils *Phytolacca decandra*, which have apparently become strongly aggressive under changed conditions. These are some of the instances which may show that predominance is not in consequence of change of country and introduction to new soil.

In many cases it is easy to explain why a plant, once introduced, should take a strong and persistent hold and spread rapidly. In others we discern nothing in the plant itself which should give it advantage. *Lespedeza striata* is a small and insignificant annual, with no obvious provision for dissemination. It is a native of China and Japan. In some unexplained way it reached Alabama and Georgia and was first noticed about thirty-five years ago; it has spread rapidly since, especially over old fields and along road-sides, and it is now very abundant up to Virginia and Tennessee, throughout the middle and upper districts, reaching even to the summits of the mountains of moderate elevation. In the absence of better food it is greedily eaten by cattle and sheep. The voiding by them of undigested seeds must be the means of dissemination; but one cannot well understand why it should spread so widely and rapidly, and take such complete possession of the ground. It is one of the few weeds which are accounted a blessing.

Professor Claypole, of Antioch College, Ohio, has recently contributed to the Third Report of the Montreal Horticultural Society (1877–8), an interesting Essay, On the Migration of Plants from Europe to America, with an Attempt to explain Certain Phenomena connected therewith. The phenomena which he would explain are the abundant migration of numerous weeds from Europe to the shore of North America, while others fail to come, and the general failure of North American weeds to invade Europe. We have offered a fairly good explanation of the first. And Professor Claypole goes far toward explaining the second when he notes that seed is (or formerly was) mainly brought from the Old World to the New, and the same may be said of cattle and other emigration; that the cooler and shorter summer of the north of Europe renders the ripening of some seed precarious, etc. He does not mention the fact that American plants by chance reaching

Europe have to compete with a vegetable world in comparatively stable equilibrium of its species, while European weeds coming —or which formerly came—to the United States found the course of nature disturbed by man and new-made fields for which they could compete with advantage. But his ingenious hypothesis is that weeds have a peculiarly "plastic nature, one capable of being moulded by and to the new surroundings," by which the plant "ere long adapts itself, if the change is not too great or sudden, to its new situation, takes out a new lease of life, and continues in the strictest sense a weed;" "that the plants of the European flora possess more of this plasticity, are less unyielding in their constitution, can adapt themselves more readily to new surroundings," and that it is "the lack of this plasticity in the American flora which incapacitates it from securing a foot-hold and obtaining a living in the different conditions of the New World;" that although "in the Miocene era the European and American floras were very much alike," yet "since that era the European flora has been vastly altered, while the American flora still retains a Miocene aspect, and is therefore the elder of the two;" "that this long persistence of type in the American flora may have induced, by habit, a rigidity or indisposition to change;" that "the European is thus better able to adapt itself to the strange climate and conditions—that is, to emigrate—than the American:" and thus, being more plastic or adaptable it succeeds in the New World, while the less adaptable American flora fails in the Old World."

So far as we know, the greater plasticity of European as compared with American plants is purely hypothetical. "More plastic" would mean of greater variability, which, if true, might be determined by observation. Because Europe once had more species or types in common with North America than it now has, it does not seem to follow that the former has "a younger plant-life," or that its existing plants are more recent than those of the American flora. And as already intimated, so refined an hypothesis is hardly necessary for the probable explanation of the predominance of Old World weeds in the Atlantic United States.

Mr. Henslow, in his remarkable memoir, On the Self-Fertilization of Plants (which we reviewed in the June number of this Journal) derives from different but equally theoretical premises an opposite conclusion,—namely, that weeds or intrusive and dominant plants in general, and of great emigrating capabilities, have "a longer ancestral life-history than their less aggressive relatives." He also maintains that weeds, and plants best fitted for domination in the manner of weeds, possess a common characteristic to which this dominance may be attributed, namely, that they are in general self-fertilized

plants. A rapid generalizer might find confirmation of this in the converse, which is obviously true, that plants with blossoms very specially adapted for cross-fertilization by particular insects, and therefore dependent on such special aid, are comparatively local and unaggressive; yet some of these are widely distributed. It will also be understood that self-fertilization may give advantage to an intruding plant at the outset, by enabling an exceptionally well-fitted individual to initiate a favored race. And self-fertilization, with its sureness, would always be most advantageous unless cross-fertilization brings some compensatory advantage greater on the whole than that of immediate sureness to fertilize.

But the test of the theory is, whether weeds and emigrating herbs in general are more self-fertilizing or less subject to cross-fertilization than the majority of related plants, and whether many or any of them are actually self-fertilized through a succession of generations. It seemed to us that, in a limited way, the weeds which Europe has given to North America might answer this question. To keep within bounds and to have a case with all the data unquestionable, we will collate the weeds of European parentage which evince a dominating character in the United States east of the Mississippi, referring for the purpose to the Manual of the Botany of the Northern United States and Chapman's Southern States Flora. The latter, however, adds not a single weed from Europe of any predominance. We include only those which have taken a strong hold and become prominent either by their general diffusion over the area or by taking marked possession of certain districts. For examples of the latter take *Echium vulgare* in Virginia, *Ranunculus bulbosus* and *Leontodon autumnale* in Eastern New England, and *Genista tinctoria* which covers certain tracts in the eastern part of Massachusetts, although nearly unknown elsewhere. We must include several species which as weeds came from Europe, although they are probably, some of them undoubtedly, indigenous to some part of the United States.

The following are the herbaceous plants naturalized from Europe and of an aggressive character in the Atlantic United States. Herbs of recent introduction, and those of however ancient naturalization which have not either spread widely or increased greatly over a considerable district, are omitted.

The 18 species in italic type, nearly half of them grasses, are probably indigenous to some portions of North America. In some cases the introduced and the indigenous plants have come into contact.

Ranunculus bulbosus.
Ranunculus acris.
Nasturtium officinale.
Sisymbium officinale.
Brassica Sinipistrum.
Raphanus Raphanistrum.
Capsella Bursa-pastoris.
Reseda Luteola.
Saponaria officinalis.
Silene inflata.
Lychnis Githago.
Stellaria media.
Portulaca oleracea.
Malva rotundifolia.
Genista tinctoria.
Trifolium arvense.
Trifolium agrarium.
Trifolium repens.
Daucus Carota.
Pastinaca sativa.
Conium maculatum.
Tussilago Farfara.
Inula Helenium.
Gnaphalium uliginosum.
Anthemis Cotula.
Achillæa Millefolium.
Tanacetum vulgare.
Leucanthemum vulgare.
Cirsium arvense.
Cirsium lanceolatum.
Lappa officinalis.
Cichorium Intybus.
Leontodon autumnale.
Taraxacum Dens-leonis.
Plantago major.
Plantago lanceolata.
Anagallis arvensis.
Verbascum Thapsus.
Verbascum Blattaria.
Linaria vulgaris.
Mentha viridis.
Mentha piperita.
Calamintha Nepeta.
Calamintha Clinopodium.
Nepeta Cataria.
Nepeta Glechoma.
Marrubium vulgare.
Galeopsis Tetrahit.
Leonurus Cardiaca.
Lamium amplexicaule.
Echium vulgare.
Symphytum officinale.
Echinospermum Lappula.
Cynoglossum officinale.
Solanum nigrum.
Chenopodium album.
Chenopodium hybridum.
Chenopodium Botrys.
Polygonum aviculare.
Polygonum Convolvulus.
Rumex crispus.
Rumex sanguineus.
Rumex Acetosella.
Allium vineale.
Alopecurus pratensis.
Phleum pratense.
Agrostis vulgaris.
Agrostis alba.
Dactylis glomerata.
Poa annua.
Poa compressa.
Poa pratensis.
Poa trivialis.
Eragrostis poæoides.
Festuca ovina.
Festuca pratensis.
Bromus secalinus.
Lolium perenne.
Triticum repens.
Triticum caninum.
Anthoxanthum odoratum.
Panicum glabrum.
Panicum sanguinale.
Panicum Crus-galli.
Setaria glauca.
Setaria viridis.

The plants of this list, regarded as weeds, are of very various character; and several of them, such as White Clover and most of the grasses, where most dominant, do not fall under the ordinary definition of weeds at all, but under that of plants useful to the farmer. Some, like Purslane, are only garden-weeds; some belong to pastures and meadows; others affect road-sides. The fewness of European corn-weeds is remarkable. Chess and Corn-cockle (*Lychnis Githago*) are the only ones on the list. Corn Poppy, Blue-bottle and Knapweed (*Centaurea Cyanus* and *C. nigra*) and Larkspur are conspicuously wanting; but the last two are not wholly unknown in some parts of the country.

But the only question before us is, whether these plants introduced from Europe are or are not self-fertilized, or more habitually so than others, so that this may be accounted an element of their predominance. Apparently this question must be answered in the negative. The question is not whether they are self-fertilizable. The great majority of plants are so, even of those specially adapted for intercrossing. The plants of this list appear to belong to the *juste milieu.* Only one (*Rumex Acetosella*) is completely diœcious; a few are incompletely diœcious or polygamous; the two species of *Plantago* are dichogamous to the extent of necessary dioicism or monoicism; a large number of the corolline species are either proterandrous or proterogynous, including two or three anemophilous species,

and all the Grasses (which form the last quarter of the list) are anemophilous and more or less dichogamous, and therefore not rarely cross-fertilized. Of those which are not anemophilous we notice none which are not habitually visited by insects (except perhaps *Gnaphalium uliginosum*), and which therefore are almost as likely to be cross-fertilized as close-fertilized; while in not a few (such as the *Compositæ* generally and most of the other *Gamopetalæ*) the arrangements which favor inter-crossing are explicit. There is no cleistogamous and therefore necessarily self-fertilized plant in the list, except *Lamium amplexicaule*, which also cross-fertilizes freely.

In California the prevalent weeds are largely different from those of the Atlantic States and, as would be expected, are mostly of indigenous species or immigrants from South America; yet the common weeds of the Old World, especially of Southern Europe, are coming in. The well-established and aggressive ones, such as *Brassica nigra*, *Silene Gallica*, *Erodium cicutarium*, *Malva borealis*, *Medicago denticulata*, *Marrubium vulgare* and *Avena sterilis*, were perhaps introduced by way of Western South America. They are mostly plants capable of self-fertilization, but also with adaptations (of dichogamy and otherwise) which must secure occasional crossing.

We cannot avoid the conclusion that self-fertilization is neither the cause, nor *a* perceptible cause of the prepotency of the European plants which are weeds in North America.

A cursory examination brings us to a similar conclusion as respects the indigenous weeds of the Atlantic States, those herbs which under new conditions, have propagated most abundantly and rapidly, and competed most successfully in the strife for the possession of fields that have taken the place of forest. The most aggressive of these in the Northern States are *Epilobium spicatum* in the newest clearings, which is dichogamous (proterandrous) to a degree which practically forbids self-fertilization; and in older fields, *Asclepias Cornuti*, which is specially adapted for cross-fertilization by flying insects; *Antennaria plantaginifolia* and *A. margaritacea*, which are diœcious; and next to these perhaps the two wild Strawberries, then *Erigeron annuum* and *E. strigosum*, with certain Asters and Golden-rods, all insect-visited and dichogamous, and *Verbena hastata*, *urticifolia*, etc., the frequent natural hybridization of which testifies to habitual intercrossing.

Those who suppose that only conspicuous or odorous flowers are visited by flying insects should see how bees throng the small, greenish, and to us odorless blossoms of *Ampelopsis* or Virginia Creeper and of its Japanese relative.

ART. XXVII.—*On a possible cause of variation in the proportion of Oxygen in the Air*; by EDW. W. MORLEY, M.D., PH.D., Professor of Chemistry in Western Reserve College, Hudson, Ohio.

PROFESSOR LOOMIS has proposed the theory that certain great and sudden depressions of temperature at the surface of the earth are caused, not by the transfer of cold air from higher to lower latitudes, but by the vertical descent of air from cold elevated parts of the atmosphere. The evidence supporting this theory was published in this Journal in January and July, 1875. It occurred to the writer some time since that if this theory were true, as the evidence makes very probable, the air at the surface of the earth during such a great and sudden depression of temperature might well contain a smaller proportion of oxygen than the average. Dalton, reasoning from the fact that oxygen has a greater specific gravity than nitrogen, argued that the proportion of oxygen to nitrogen in the atmosphere should decrease with increasing altitude above the earth's surface; whether he clearly enough recognized that such a regular decrease would be realized only in an atmosphere in a state of equilibrium undisturbed by convection currents, the writer does not know, not having seen Dalton's memoir. Such a decrease of atmospheric oxygen with increasing altitude has not yet been detected by analysis, although the amount of decrease, on the theory that oxygen and nitrogen are distributed in the atmosphere according to the law which would prevail in case of equilibrium, is so rapid that it would be detected with ease, even in altitudes attained in every holiday ascent of a balloon. This decrease may be calculated from the formula $R = R_0 0{\cdot}9832960^{H}$, where H denotes the height above the earth's surface expressed in kilometers, R_0 denotes the ratio of the tension of oxygen to that of nitrogen at the surface of the earth, and R denotes the same ratio for the height H. The constant is computed from the determinations by Regnault of the weights of a litre of oxygen and of nitrogen, and of the specific gravity of mercury. The following table gives in the second column the ratio of the tension of oxygen to that of nitrogen at the height in kilometers given in the first column, and the per cent of oxygen at the same height in the third column. The per centage of oxygen at the earth's surface assumed in the table is that used in the tables for gas analysis in Bunsen's Gasometrische Methoden.

It will be seen that the composition here calculated for a height of a single kilometer is so different from that at the surface that analysis of no very refined accuracy would detect the

riation with ease. But no such variation has been detected en in samples of air collected at the greatest elevations :ainable.

Height, :ilometers.	Ratio of O to N.	Per cent of O.	Height, Kilometers.	Ratio of O to N.	Per cent of O.
0	26·52 %	20·96 %	10	22·41 %	18·31 %
1	26·08	20·68	20	18·93	15·92
2	25·64	20·41	30	16·00	13·79
3	25·21	20·14	40	13·52	11·91
4	24·79	19·87	50	11·42	10·25
5	24·38	19·60	60	9·65	8·80
6	23·97	19·34	70	8·16	7·54
7	23·57	19·07	80	6·89	6·45
8	23·18	18·82	90	5·82	5·50
9	22·79	18·56	100	4·92	4·69

But although this is the case, it is certain that in the atmo- ıere of the same place at different times the oxygen varies more than one-fortieth of its average amount. Variations large as this are rare, but variations of the one-hundredth or ›-hundredth part are common. It therefore seemed to the iter proper to examine whether facts bear out the conjecture .t certain great and sudden local depressions of temperature caused by the descent of cold air from the upper part of atmosphere, and that such air may by its poverty in oxygen ow some light on a question in meteorology and a question ıcerning the physics of a mixture of different gases.

In the number of Wiedemann's Annalen for April of the ·rent year, Jolly has published the results of numerous and y accurate analyses of atmospheric air. He asserts a con- :tion between the variations in composition detected and the ection of the winds when the sample was collected. He ısiders himself justified in concluding that the atmosphere tropical regions is poorer in oxygen than that of polar ;ions, and supposes that at the equator more oxygen is con- ned in processes of oxidation than is set free by those of luction, while the opposite is true near the poles. Since no ference in the composition of the atmosphere at the equator l at the poles has been detected, while on this theory the ference must be one large enough to account for the extreme :iations found in temperate regions, and to account for them er such abnormal air had been exposed to admixture with of a different composition during a passage of thousands of les, the writer fears that the theory of Jolly will need ther proof. Other reasons for a similar doubt will suggest :mselves.

On the writer's theory, a sample of air collected at the center an area covered by a descending current of cold air would

at some given instant be a sample fresh from the upper part of the atmosphere, but little exposed to admixture on the way. If before its descent it had remained at a great height for a long time, it might well have lost some of the oxygen which it contained when it was at some previous time at the level of the sea, and the difference might be enough to be detected. An observer at one side of this central point would have samples more or less mingled with surface air; but even then, a deficiency of oxygen might be detected by accurate analysis.

The writer hopes to make arrangements for the regular collection of samples at points which Professor Loomis has indicated as regions of frequent descent of cold air from great heights. But while laying plans for the work, he has thought best to ascertain whether some light on the changes in the constitution of the atmosphere might be obtained by analyzing samples of air collected at home. Having an apparatus for gas analysis lately constructed for the study of the gas issuing from the numerous gas wells of his vicinity, he used this for such determinations. In general, the apparatus is constructed on the plan of McLeod's modification of Frankland and Ward's apparatus. But some important modifications have been introduced, and excellent workmanship was bestowed on details. Some such points but slightly concern analyses by explosion. The connection between the eudiometer and absorption tubes is novel, and has worked well. This will be described in some proper connection. Here will be described everything necessary for a judgment of the accuracy of the analyses to be cited.

The eudiometer and pressure tubes were made from the writer's drawings by Geissler, whose recent death is a loss to science, and a personal loss to so many who have been aided by him. The stop-stocks at the top of these tubes will retain a Torricellian vacuum for weeks. The internal diameters of the tubes are 20·9 and 10·7 millimeters. At the lower end of the eudiometer tube is a glass stop-cock, the use of which is simply to permit the ready cleaning of the tube. Its glass plug is withdrawn, and in place of it is put one of vulcanite so bored that acids or water can be aspirated through the eudiometer without dismounting it and without drawing off the mercury from the pressure tube. The stop-cock at the top of the eudiometer tube is also provided with a similar plug for the same purpose. The pressure and eudiometer tubes are surrounded by a stream of water entering at the top of the pressure tube and running away from near the bottom of the two. The level of water is kept constant by a device similar to that of Thomas, described in a late number of the Journal of the Chemical Society, but perhaps superior to his in some respects. The flow of mercury to and from the movable

reservoir is controlled by an iron stop-cock which is attached to the iron tripod support of the whole apparatus. The plug of this stop-cock is vertical, and is prolonged by a shaft which puts it within easy reach of the observer. By means of a long handle on this shaft, the stop-cock can be moved with the greatest delicacy. From this stop-cock, an iron tube, cast in the same piece, extends under the ends of the glass tubes of the apparatus, and two small iron tubes rise from this horizontal tube; these last meet the glass tubes and are connected with them by short tubes of patent black rubber containing no free sulphur. The connectors are tied so as to endure the pressure of mercury having a head of several feet, and are surrounded with mercury so as to be absolutely air-tight. The plug of the iron stop-cock is also so surrounded with mercury that the entrance of air is absolutely impossible, and the same precaution was taken at the junction of the two small iron tubes with the horizontal tube. The cast iron of this tube and stop-cock is well japanned, and no leakage through its pores has occurred.

The measurement of the volume of gas in such an apparatus demands an accurate adjustment of the level of the mercury in the eudiometer tube to one of the marks of the graduations. Such an adjustment can be accurately made by admitting mercury very slowly from the reservoir, and closing the stop-cock at the required moment. But if now the temperature of the gas be not quite constant, the adjustment can be renewed for a second reading only by letting in or out a column of mercury of several millimeters, again permitting it very slowly to approach the proper level, and stopping at the instant of contact. It is quite impossible to open the stop-cock, admit the twentieth or fortieth of a millimeter of mercury, note the right instant, and then again close the stop-cock. But for accurate work, the means of altering the level of the mercury by such small quantities, and of doing it by a continuous movement, seemed important. In the end, therefore, of the horizontal iron tube, there works a plunger, packed with great care, which can be moved in or out by a screw. By means of this micrometric movement, the level of the mercury which has been adjusted by the stop-cock can be altered with the greatest delicacy, and readjusted till perfect steadiness is attained. Danger of leakage through the washers around the plunger was prevented by providing a seat into which, when the plunger is screwed quite home, it fits so as to cut off connection between the pressure tube and the rest of the apparatus. The mercury in the pressure tube is, by the use of this valve, always kept at such a height that any possible leakage is that of mercury outward, and not of air inward.

The eudiometer and pressure tubes are cemented into the brass cap of the glass cylinder containing the water intended to keep all parts of the apparatus at the same temperature. The level of the two graduations with respect to each other is therefore constant.

When the writer planned to make analyses of air in order to detect if possible some law in its variations of composition, he expected to have to do with quantities but little larger than the errors of observations. Some thought was therefore given to the methods of keeping such errors as small as possible. It was hoped that if the probable error of a determination of oxygen with this apparatus was not larger than the probable error of the analyses made by Bunsen in January and February, 1846, the object of the analyses would be attained. Such analyses as those of Bunsen would abundantly serve to establish variations of the four hundredth part of the average amount of oxygen contained in the atmosphere. The writer expected to have commonly to do with such variations, and therefore computed the comparative accuracy of analyses of air made with the long eudiometer of Bunsen's experiments, and with the apparatus used in the present work. In the first analysis by Bunsen of the air of January ninth, the length of the column of gas in the eudiometer was in round numbers, 840 millimeters, and its tension 510. The tension was determined by four readings, and the apparent volume of air taken by one reading. An error in the last reading would produce also an error of the same sign in the observed tension, so that these two errors are not independent. Their influence on the result is therefore computed by simply adding them; the other errors are independent of this joint error and of each other. And the influence of the four independent errors on the result is computed by taking the square root of the sum of their squares. If we repeat this computation for the different volumes and tensions of the second and third measurements, referring all the probable errors to the volume of air first taken, and obtain the probable errors of the three measurements, we may obtain the probable error of the final result by adding the square of the first probable error to the squares of the third parts of the second and third, and taking the square root of the sum.

The probable error of a single reading of the level of the mercury in Bunsen's experiments is not given; but we may compare the two methods by assuming arbitrarily some probable error, provided that we assume the same error in both computations. The first column of the following table gives the influence of a probable error of one-tenth of a millimeter in a single reading in each of the three measurements of the analysis quoted from Bunsen.

In the measurement of a volume of gas with the Frankland and Ward or McLeod apparatus, the mercury is brought to that mark in the eudiometer tube which will give a suitable tension, and the height in the pressure tube at which the mercury stands is determined. An error in determining the volume of gas in the eudiometer tube involves an error of the same sign in the observed tension. If we add these two dependent errors we have one of the two independent errors affecting this mode of measurement, the other being the error probably made in determining the upper level of the mercury in the pressure tube. Adding the squares of these two and taking the square root, we have the probable error of a measurement with the apparatus. If we treat the second and third measurement in the same way, and compute the effect of these three probable errors on the final result, we get the numbers in the second column of the following table.

Probable errors of measurements of gas, and of final results, occasioned by a probable error of the tenth of a millimeter in each reading.

	In Analysis cited from Bunsen.	With Frankland and Ward apparatus.
In measurement of air taken	0·046 %	0·034 %
In measurement of air and hydrogen	0·050	0·042
In measurement after explosion	0·039	0·031
Probable error of result	0·051	0·038

It is obvious that with the same error probable in each reading, the use of the rapidly working apparatus involves no sacrifice of accuracy to convenience, as far as the conditions of *observation* are concerned.

To obtain the degree of accuracy needed for the present purpose, it is necessary to take account of the expansion of the mercury in the column which measures the pressure, and also of the linear expansion of the scale which measures the tension, and of the cubical expansion of the eudiometer tube. Since all these are at the same temperature with the gas to be measured, it is easy to prepare a table giving the correction not only for the expansion of the gas but also for the expansion of mercury, scale and eudiometer. Such a table, giving on a single page, for every tenth of a centigrade degree from zero to thirty degrees, the logarithmic factor to be added to the logarithms of the observed volume and observed tension, makes the work of reduction very slight. Most tables of correction of the volumes of gas contain a logarithm to be subtracted; for convenience it should be additive; and five places of decimals should not be exceeded. Unless measurements can be made ten times more accurate than Bunsen's, five places of logarithms distinguish smaller differences than observation deals with; five places permit instant interpolation for hundredths of a

degree, and a greater number waste time and possess no advantage whatever.

The eudiometer was calibrated by filling it with air-free water, and weighing the quantity expelled as the mercury rose to each successive mark of the graduation. This was done four times for each division; the probable error of a single determination was found to be 8·6 milligrams of water. The results were all reduced to the temperature of melting ice. There were seventeen divisions in the eudiometer tube, now broken, which was used in all the analyses in this paper. The volume of gas to be measured was always brought to one of the two divisions which permitted measurement under the most favorable conditions, and its tension determined; it was then brought to the other division, and its tension again determined. Two independent measurements thus obtained eliminated the chance of error in identifying divisions on the scale, and also afforded the means of ascertaining the probable error of a measurement. In the analyses contained in this paper, the quantity of air taken was unfortunately limited by the circumstance that the collecting tubes at hand were small; the probable error of the results so far obtained is therefore much greater than is due to the care used in observing. In analyses made after the present month this mistake of judgment will be corrected. The mean quantity of air taken in an analysis so far has been 38·9 cubic centimeters measured at zero and 760 millimeters. From 196 pairs of measurements it has been computed that the probable error of a single determination of volume is its 5800th part. Hence the probable error of a determination of oxygen in the air is the 7200th part, and the probable difference of two determinations on the same sample is the 5100th part. A second analysis was always made when the first showed a deficiency of oxygen. A comparison of the results will show whether the accuracy indicated by computation was obtained.* The writer has in hand an entirely new construction of the pressure tube, and some modifications of the optical appliances for reading the level of the mercury in the eudiometer tube, by which he hopes considerably to lessen this probable error.

The samples of air analyzed were collected in the open country in glass vessels with due care as to admixture with the air from the collector's lungs, preserved over mercury, freed from carbonic acid, and exploded with hydrogen, of proved purity, obtained by galvanic decomposition of water. But

* The divergence of the second result of February 26th from the first is due to the fact that in the second analysis the hydrogen used was not pure. As none of the sample remained for a third experiment, the second result is given in confirmation of the first. But this pair of results should not be used in computing probable errors.

some samples were collected in clean stoppered and capped bottles, and kept for a short time by inverting the bottle in the cap which had been filled with water. In this case the air was withdrawn for analysis with a Tœpler's mercury pump.

The table gives in the first column the date, in the second, the mean temperature of the day at this place as determined by three observations. In the third, on the days when analyses were made, the hour of collecting the sample is given, fractions of hours being disregarded. In the last two columns are given the hundredths per cent found by analysis, the figures twenty and the decimal point being suppressed. The figures ninety-six, for instance, in this column mean 20·96 per cent of oxygen. Within the time covered by the analyses now published, there were several well marked great and sudden depressions of temperature, and the figures show the falling off in the proportion of oxygen in the air at these times to be as well marked as the depression of temperature. The deficiency is not proportionate to the depression of temperature; this could not be expected.

It may be said that these analyses were commenced in March, 1878, but in December of that year, a doubt was felt whether it were absolutely certain that in every case the air and hydrogen had been completely mixed before explosion. In test cases, the air and hydrogen had been permitted to diffuse into each other for eighteen hours before explosion, and the results were the same as in the usual course of analysis; but the analyses are not here given, although they contain only evidence perfectly agreeing with that here presented. In all the analyses here printed, the air and hydrogen were known to be thoroughly mixed; they were driven as rapidly as possible through a capillary tube twelve or twenty times. All made between the first and last dates of the table are given without selection, except that some were rejected for obvious instrumental errors.

The remarkable deficiency of oxygen observed on the twenty-sixth of February seems affected with no reason for doubt. On Sept. 16, 1878, two very careful analyses of the same sample gave 20·49 and 20·46 per cent of oxygen. On July 19, and Nov. 10, 1877, Jolly found 20·56 per cent. The Neues Handworterbuch der Chemie, i, 856, cites an analysis of air from the Bay of Bengal showing 20·46 per cent, one of air from near Calcutta, showing 20·39 per cent, and one of air from near Algiers, showing 20·41 per cent. That Jolly and the writer have found air almost as deficient in oxygen as the three last will lessen the probability that the air of the surface of the earth in the Torrid zone is normally poor in oxygen. One of the first cases of a supposed descent of cold air from

Analyses of Air,

Showing deficiency of Oxygen attending sudden depression of temperature.

Winter of 1878–1879.

Date.	Mean Temperature. F.	Hour of taking sample.	Oxygen.		Date.	Mean Temperature. F.	Hour of taking sample.	Oxygen.	
Dec. 28	---	4 P. M.	98	96	Feb. 16	26·3	9 A. M.	95	
29	14·8				17	25·7			
30	19·3				18	24·1			
31	16·2				19	23·2			
Jan. 1	23·8				20	18·9	6 P. M.	87	87
2	7·6	4 P. M.	91	92	21	17·9			
"		10 P. M.	90	89	22	---			
3	−7·2	9 A. M.	90	91	23	25·4			
"		1 P. M.	96	97	24	21·5			
4	2·2				25	37·1			
5	7·7				26	22·3	3 P. M.	45	50
6	13·5	3 P. M.	97		27	12·8	9 P. M.	77	80
7	19·3				28	24·1			
8	26·4				Mar. 1	38·7			
9	16·9				2	29·7			
10	9·6	10 A. M.	96		3	34·3			
11	20·6				4	37·2			
12	26·0				5	35·9			
13	27·9				6	41·6			
14	26·3				7	34·1			
15	25·8				8	51·0			
16	28·5				9	61·8			
17	29·1				10	58·4			
18	---				11	54·4			
19	15·9				12	40·3			
20	9·9				13	39·4			
21	26·0				14	29·3			
22	37·7				15	22·8	9 A. M.	88	84
23	28·3				"		9 P. M.	84	86
24	32·5				16	25·3	9 P. M.	92	92
25	32·4				17	24·5	9 A. M.	89	90
26	23·7				18	24·3			
27	44·9				19	28·7			
28	37·4	9 A. M.	96		20	33·1			
29	31·5				21	32·3			
30	---				22	34·6			
31	28·2				23	31·7			
Feb. 1	18·5	9 A. M.		96	24	40·1			
"		9 P. M.	94	94	25	30·1			
2	19·8	9 A. M.	91	93	26	38·2			
"		9 P. M.	82	80	27	35·1			
3	26·8				28	44·8			
4	28·1				29	45·9			
5	31·5				30	33·3			
6	28·3				31	31·9			
7	25·1				Apr. 1	33·7			
8	28·5				2	29·9			
9	24·0				3	25 at	9 A. M.	77	79
10	32·7				"	2 P.M.	9 P. M.	85	87
11	54·4				4	27·1	9 A. M.	80	80
12	26·5				"		9 P. M.	88	85
13	15·6				5	28·2	9 A. M.	77	77
14	5·8				"		9 P. M.	86	82
15	11·1	4 P. M.	88	86	6	39·4			

elevation mentioned by Loomis occurred in the warmer rts of this country. If his theory finds favor, and the writer's njecture is correct, it will be presumed that the three samples ed in the Handworterbuch from the still warmer regions of e earth were taken in the midst of such a mass of cold air scending from, and retaining the composition of, the upper rts of the earth's atmosphere.

The analyses here printed should not be used in determining e average composition of the air by combining analyses from sources. Whether the writer's conjecture is correct or not, has enabled him to select times for taking samples of air rying widely from the average; and to such times his analy- s have been commonly limited, only occasionally including sample of presumably normal air to serve as a check on the normal.

Vestern Reserve College, Hudson, Ohio, June 12, 1879.

RT. XXVIII.—*Principal J. W. Dawson's criticism of my Memoir On the Structure of* Eozoon Canadense *compared with that of Foraminifera;* by K. MÖBIUS, Professor of Zoology at Kiel.*

IF it were true that "the organic character of Eozoon is at esent generally admitted," as Dr. Dawson says in his criticism my memoir, I could have spared myself the trouble of borating, and others that of reading, my studies. But ery one who has paid attention to this question knows that s statement of Dr. Dawson is not correct. As long as two ferent opinions about one object in nature are maintained, d on both sides by men whose learning and honesty in the irch for the truth cannot be questioned, so long are renewed idies and descriptions of the differently judged object a scientic duty for all who believe that they have the true explanation. r every phenomenon in nature but one thoroughly true explanation is possible. This principle, as stated in my memoir 178), has guided me in preparing it for the scientific public.

Dr. Dawson says further, "As fast as one opponent" (against e organic character of Eozoon) "is disposed of, another pears." And he rises, himself, to dispose of me, the last of e opponents.

' For Dr. Dawson's paper see this Journal, xvii, 196, March, 1879.
Thinking that Professor Möbius should have, if he desired, an opportunity to ly to Dr. Dawson's criticism, and that science would profit thereby, we offered the pages of this Journal, and stated that we should be pleased if he would upy them and give his views on the subject; informing him, at the same time order to remove any objections that might arise in his mind), that there would no rejoinder in this Journal. Professor Möbius has accordingly prepared for the article now published. J. D. D.]

No one should be able to do so better than he. It was he who described the *Eozoon Canadense* as an organism; who has, moreover, a very fine collection of specimens of Eozoon, and has studied the Eozoon *in situ* and is fully acquainted with the literature relating to it. I could not, indeed, have wished for a more experienced reviewer, to show me where I had fallen into error and where I had found the truth.

It is Mr. Dawson's belief that few scientific men are in a position fully to appreciate the evidence respecting the organic character of Eozoon; that this is true of the geologists and mineralogists, because they do not yet agree with regard to the nature of the rocks in which it occurs; and of the biologists, because "they are but little acquainted with the appearance of foraminiferal organisms when mineralized with silicates." "Nor are they willing," he says, "to admit the possibility that these ancient organisms may have presented a much more generalized and less definite structure than their modern successors. Worse, perhaps, than all these, is the circumstance that dealers and injudicious amateurs have intervened and have circulated specimens of Eozoon, in which the structure is too imperfectly preserved to admit of its recognition." These are the principal points in the introduction to Principal Dawson's criticism on my paper. He continues: "The memoir of Professor Möbius affords illustrations of some of these difficulties in the study of Eozoon."

I hope Principal Dawson will concede that, in my memoir, there is no evidence that the different hypotheses with regard to the geological character of the strata in which the Eozoon occurs have puzzled me; nor that any previously conceived hypothesis has influenced me in my conclusions. To hypotheses of this kind I have briefly alluded in the last chapter of my memoir where I say: "While excluding Eozoon from the organic world by scientific arguments, it is by no means maintained that in the Laurentian period there may not have existed organisms. It is possible that the graphite of the Laurentian beds may have originated from organisms." These words ought plainly to have shown Mr. Dawson that no geological hypothesis compelled me in advance to deny the organic nature of Eozoon. On the contrary, in the beginning of my studies I hoped to gain conclusive evidence in favor of the organic character of Eozoon, as I have stated in my memoir, chapter VI: "It is to me a source of regret that I cannot say to Messrs. Dawson and Carpenter, who have so kindly aided me in my work, that *Eozoon Canadense* must be considered, from my researches also, a fossil Foraminifer." I quote these words here for the benefit of those readers of Principal Dawson's criticism who are not acquainted with my memoir.

I was familiar with the structure of fossilized Foraminifera, as can be seen from several notations and figures in my paper. Nor was I unwilling to admit that the structure of Eozoon might be different from that of modern Foraminifera, as is evident from the following words in my memoir (p. 188):

"If all the structures of Eozoon, in the same layers and forms that they have in the best specimens circulated by Dawson and Carpenter, were indeed produced by living beings, the living Eozoon must have had a nature totally different from that of all plants and animals we know. If it were possible to prove that Eozoon is a fossil and not a mineral, we must then make two divisions of organic bodies, viz: 1, organic bodies with protoplasmic nature (all plants and animals); 2, organic bodies with eozoonic nature (*Eozoon* Dawson). In the genealogical line, in which the theory of evolution or descent unites all protoplasmic beings, there is no place for Eozoon."

Further, not a single one of all the specimens of Eozoon, which I studied, came from the hands of "dealers or injudicious amateurs," but all directly or indirectly from Messrs. Dawson and Carpenter. This I have said repeatedly in my paper. I am consequently much surprised at the words of Dr. Dawson: "The memoir of Professor Möbius affords illustrations of some of these difficulties in the study of Eozoon."

Why should Principal Dawson write thus about my memoir if he has read it throughout with attention and understanding? It bears full evidence that I had not to struggle in the slightest degree with such difficulties.

But Principal Dawson has read my paper, and he points out *two errors* in it, viz: 1, I have (on p. 180) taken as a figure of full natural size a very large specimen of Eozoon, which Principal Dawson on plate III of his "Dawn of Life" has presented of half the natural size; 2, on the same page I say: "We know specimens of Eozoon which have more than fifty whitish and greenish laminæ," on which Mr. Dawson remarks, that they often have more than a hundred.

For these corrections I offer my sincerest thanks. Other substantial errors he has not mentioned. If he will do so, I shall be further grateful to him. For if in a paper of mine an error is unveiled, the first displeasure I feel in having not been careful enough to avoid making a mistake, is very soon effaced by the satisfaction of seeing the pure and certain truth come forth. No naturalist, in any branch of science, has ever discovered and brought out at once the whole truth in all directions. It is evident that those two mistakes are of no significance in deciding the question whether *Eozoon Canadense* is an organism or not.

But Dr. Dawson writes further (p. 197): "Möbius has

had access merely to a limited number of specimens mineralized with serpentine. These he has elaborately studied, and has made careful drawings of portions of their structures, and has described these with some degree of accuracy; and his memoir has been profusely illustrated with figures on a large scale. This, and the fact of the memoir appearing where it does, convey the impression of an exhaustive study of the subject, and since the conclusion is adverse to the organic character of Eozoon, this paper may be expected, in the opinion of many not fully acquainted with the evidence, to be regarded as a final decision against its animal nature. Yet, however commendable the researches of Möbius may be, when viewed on the evidence of the material he may have at command, they furnish only another illustration of partial and imperfect investigation, quite unreliable as a verdict on the questions in hand."

On reading these lines one cannot but be astonished and ask, whether they were written by the same author, who said a few lines before: "Professor Möbius is a good microscopist, fairly acquainted with the modern Foraminifera, and a conscientious observer." This impression he must also have gained from my paper on *Eozoon Canadense*.

Principal Dawson, in saying I have had access "*merely to a limited number of specimens*" of Eozoon, should have stated exactly how many specimens are to be studied to gain a conclusive judgment in regard to its real nature. It has often happened that biologists and paleontologists have had not more than one specimen in hand, or even not more than a part of a specimen, and notwithstanding they were in a position to determine surely its place in the organic kingdom. He says, further: "Möbius has made drawings of *portions* of the structure of Eozoon;" he does not state what structures I have omitted. I have certainly made careful drawings and descriptions of all the Eozoon-structure, which according to Messrs. Dawson and Carpenter corresponds with the chambers, the communications between them, the tubuli of the proper wall of the chambers, and the canal-system in the intermediate skeleton of Foraminifera.

Principal Dawson says again: "Möbius has described these structures with *some degree* of accuracy." It would have been more satisfactory if he had pointed out the imperfections of my descriptions, each one for itself and all without reserve. I should have been grateful for the aid in improving my descriptions of Eozoon.

Principal Dawson evidently apprehends that my "profusely illustrated" paper may convey the impression of an exhaustive study of the subject. That was indeed my purpose. Has he not read or understood my remarks (pp. 178 and 179) in regard to the necessity of many good drawings of all the structures of

Eozoon? Or, had he in writing his criticism the opinion that it would be read by those only who would never see my paper itself?

But how can he venture to say: "The fact of the memoir appearing where it does conveys the impression of an exhausting study of the subject?" A bad paper has never gained the continued assent of the public through the fame of the Journal in which it appeared. In giving my paper to the editors of the illustrious "Palæontographica" I had by no means the intention of gaining for it any higher opinion than it deserves by itself. I wished to bring it before a disinterested and judicious public; besides, I knew that the publisher of the "Palæontographica" would take care to print my drawings very exactly, and he has done so.

After having made these objections in general, Principal Dawson considers "a number of errors and omissions arising from want of study of the fossil *in situ*, and from want of acquaintance with its various states of preservation."

If Principal Dawson demands that nobody should venture to judge of the nature of Eozoon but those who have seen it *in situ*, he claims in favor of his *Eozoon Canadense* an exception over all productions of the accessible world. When writing these lines he overlooked the fact that Mineralogy, Paleontology, Botany and Zoology contain a very great number of universally appreciated memoirs concerning objects which the authors have never seen *in situ*.

It was my intention to study Eozoon from a biological point of view, which is indeed shown in the title of my memoir, viz: "*The structure of Eozoon Canadense, compared with that of Foraminifera, by my own investigations.*"

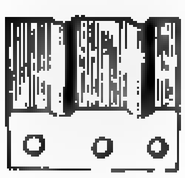
It seems strange that Principal Dawson quotes in his criticism but the first five words of this title. If it were actually so short, many things might have been left out which the real title promises. For my purpose, the examination of Eozoon from a *biological point of view*, I was in a very favorable situation, because a very large number of specimens of *Eozoon Canadense* were at my disposal, which Messrs. Dawson and Carpenter had sent directly to me or to other naturalists.

Can I now be reproached, that I accepted all specimens of Eozoon as genuine, which the two principal defendants of its animal nature had proved! But if Principal Dawson means that my drawings and descriptions were insufficient to show all variations and all degrees of preservation of his *Eozoon Canadense*, I would request him urgently to send me such specimens as will enable me to improve my researches. I shall accept them with my best thanks, study them very exactly, and will bring all I shall find conscientiously before the scientific public.

On p. 187 of my paper I say: "It is impossible to detect in any specimen of Eozoon any spot, from which there could have originated all the serpentine bodies of this specimen, and which therefore might agree with the primary chamber of Foraminifera." When Mr. Dawson, in alluding to these lines, writes (p. 198): "Möbius objects to the impossibility of detecting *regular* primary chambers like those in modern Foraminifera," he has interpolated the word, "*regular*," for the sake of the argument; he adds: "Möbius seems not to be aware that some Stromatoporæ originate in a vesicular irregular mass of cells, and that in Loftusia the primary chamber is represented by a merely cancellated nucleus." From this it is evident, that *not I*, but *Mr. Dawson* has failed here.

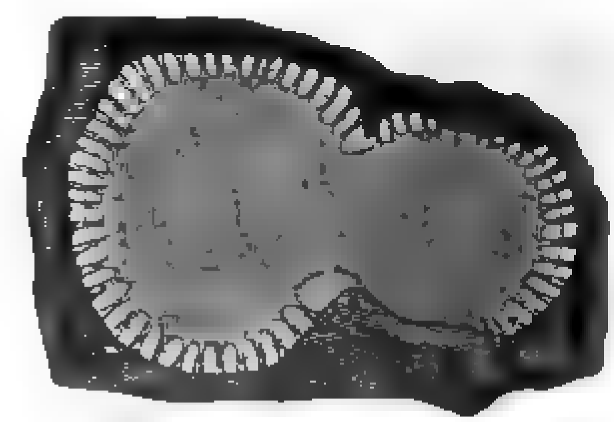
He says further: "With reference to the finely tubulated proper wall of Eozoon, Möbius has fallen into an error scarcely excusable in an observer of his experience, except on the plea of insufficient access to specimens." In writing this, Principal Dawson omitted to state that I studied only those specimens of Eozoon which had come from him and Dr. Carpenter, and that these were indeed very many in number. I beg him to read again the explanations of my drawings, and he will find in

1.



Cell-wall of Eozoon, when highly magnified; after J. W. Dawson.

2.



Tubuli in the Kempten mineral (× 220).

many places quoted: "Nummuline tubulation," written from labels by Dr. Carpenter himself on the figured preparations. But Dawson agrees exactly in regard to the "Nummuline tubulation." Both Eozoonists consider the chrysotile veins as the proper wall filled with fine cylinders of silicate. I could not detect in any specimen of Eozoon the slightest traces of such tubuli as Principal Dawson has figured in "The Dawn of Life" (p. 106). I give here a copy of this figure (1). If Eozoon did indeed contain tubuli of such organic regularity, we should have reason enough to agree with him in considering it Foraminiferal, as well as the specimen from Kempten, Bavaria, which Principal Dawson advises me to study (p. 199). I can assure him that I did so before I wrote my memoir, and from prepa-

rations which were kindly forwarded to me by Dr. Hahn at Reutlingen. I add here a drawing of the tubuli in a slice (fig. 2).

Principal Dawson remarks: "That some of Möbius's specimens have contained the proper wall fairly preserved is obvious from his own figures, in which it is possible to recognize both this structure and the chrysotile veins, though confounded by him under the same designation." Why does he not state *what* figures these are, and why has he neglected to give a copy of them in his review, since he has taken some other figures of mine as evidence of the foraminiferal character of Eozoon?

In the same paragraph Principal Dawson speaks in detail of the different difficulties met with in distinguishing the minute tubes. I quote his own words, viz: "When the proper wall is merely calcareous, its structure is *ordinarily invisible*, and it is the same when the calcareous skeleton has, from any cause, lost its transparency, or has been replaced by some other mineral substance. Even in thickish slices, the tubes, though filled with serpentine, may be so piled on one another *as to be indistinct*." Indeed these lines are quite like an esoteric Eozoon mystery; but every true natural doctrine only contains exoteric theses.

Principal Dawson speaks of my description of what he calls the "Canal system." He urges that I was mistaken in thinking that round and regularly branching stalk-like bodies are rather exceptional. I can assure him that I have found in all specimens of Eozoon circulated by Dawson and Carpenter almost only such flat and irregular branched stalk-like bodies as I have illustrated in my figures. It ought to be admitted that as soon as the first objections against the organic character of Eozoon were made, Messrs. Dawson and Carpenter distributed *only good specimens* of Eozoon; and it would be very strange, if just those of their specimens which came into *my* hands had not the genuine structure, but such qualities as speak against the organic nature of Eozoon.

Principal Dawson brings before the readers of his criticism in the figures 1 and 2 (p. 201), two of my drawings of the stalk-like bodies traversing the associated limestone and regarded by Eozoonists as casts of canals. He has chosen just those which differ very little from figures which he and Carpenter have added formerly to their descriptions of Eozoon. Why did he not copy instead of these figures, drawings of the many isolated stalk-like bodies which fill up the "canal systems" and to which I devoted a whole plate? And why does he not speak of those of my drawings which present the casts of the "canal systems" colored by Fuchsin, showing beyond doubt that these are only irregularly curved stalks or plates.

I feel sure that Mr. Dawson will also get the same views of the real forms of the "canal system" if he will only employ

my methods. The two figures which he has chosen out of my plates can only serve as evidence for the foraminiferal nature of Eozoon to those readers of Mr. Dawson's criticism, who have never had my memoir in their hands. In selecting these two figures, Mr. Dawson has plainly proved that his views as to the canal nature of the stalk-like bodies are very weakly supported.

"Another objection against the organic nature of Eozoon," says Principal Dawson, p. 200, "Möbius takes to the directions of the canals, as not being transverse to the laminae, but oblique." Here Mr. Dawson did not understand me rightly. I say, chapter IV, p. 184, in regard to the fine tubes of Foraminifera (which are regarded as resembling the chrysotile fibers), that they are usually directed transversely to the inner and outer sides of the chamber-wall, and I show this by figures of Foraminifera, for instance, by the figure of a slice of a Nummuline, which Dawson has copied, fig. 4, p. 201. My remark about the direction of the fine tubes Mr. Dawson refers to his "canal system," to which it does not belong at all. It is therefore not *I*, but *Mr. Dawson*, who makes a mistake.

Paragraph 4 of Principal Dawson's criticism (p. 200), begins with the words: "A fatal defect in the mode of treatment pursued by Möbius is that he regards each of the structures separately and does not sufficiently consider their cumulative force when taken together." Principal Dawson has either not read, or not understood, chapter VI of my memoir. In this chapter my only object was to compare the structures of Eozoon, as a whole, with the structures of Foraminifera. I am convinced that I could not better explain the structure of Eozoon than by describing first each structure particularly, before I compared them all together with the Foraminifera; and all disinterested biologists and paleontologists will agree that there is no better method of treating such an object.

Next follows, in Dr. Dawson's criticism, a *resumé* of his well-known opinions about the organic nature of Eozoon. I will only make a remark about one of the eight points which he makes. He says, point 3: "The general form, lamination and chambers of Eozoon resemble those of the Silurian *Stromatopora* and its allies, and of such modern sessile Foraminifera as *Carpenteria* and *Polytrema*." No one who is minutely acquainted with the structure of Eozoon, Stromatopora, Carpenteria and Polytrema can maintain such an opinion. If Principal Dawson had only compared my figures of *Carpenteria*, *Rhaphidodendron*, and *Polytrema miniaceum*, closely with the structures of Eozoon, he would certainly not have made this statement.

The dear old Polytrema! Ever since the celebrated Professor Max Schultze said that it resembled Eozoon, Polytrema has served ever and anon as evidence for the organic nature of

Eozoon. If Max Schultze had been acquainted with the structure of Eozoon as well as with the structure of Polytrema his histological genius would certainly have prevented him from making such an assertion.

Further on, Mr. Dawson reproaches me for saying that: "Dr. Carpenter and Principal Dawson have leaned to a subjective treatment of Eozoon, representing its structure in a somewhat idealized manner." Where did I say this? On p. 188 I said about their diagrams of Eozoon: "Carpenter and Dawson show clearly by the diagrams of *Eozoon Canadense* that they assume for the supposed living being, which has, in their opinions, formed the shell of Eozoon, the power of producing structures of organic regularity." And, further, I say: "The individual pecularities of diagrams should not exceed the limits of the known variability of the real specimens. But in the Eozoon diagrams of Carpenter and Dawson these limits are exceeded." These are my words. I am convinced that every naturalist who is free from prejudice will agree with me in regard to Carpenter's and Dawson's diagrams.

In the last page of his criticism Mr. Dawson points to his "careful examination and selection of specimens, etc., of Eozoon, in comparison with the works of others who arrive at conclusions in easier ways," and he concludes with the words: "Taken with the above cautions and explanations, the memoir of Professor Möbius may be regarded as an interesting and *useful illustration of the structures of Eozoon*, though from a point of view somewhat too limited to be wholly satisfactory." I here warn every naturalist who has not seen my memoir, not to think that it is an illustration of the organic nature of Eozoon.

The final result of my paper, that the Eozoon can not be a protoplastic organic formation, will be maintained until Principal Dawson declares that all specimens of Eozoon which he has given away are not genuine representatives of his *Eozoon Canadense*, and until he has put into the hands of naturalists who are well acquainted with the structure of Foraminifera the genuine representatives of his *Eozoon Canadense*, which shows that organic nature sustained by Carpenter and himself. If he will kindly send me such representatives of his *Eozoon Canadense*, I will willingly forgive him that he has disappointed me and other naturalists. I will examine those genuine specimens with the same care and conscientiousness; and if I find a true organic structure, I will avow, without hesitation, that the genuine *Eozoon Canadense* was an animal. The aim of all my researches is this: not that I should be the one to find the truth, but that the *truth should be found* and brought to the light. No error will be changed into truth by constantly believing, nor by persistently declaring, it as truth.

ART. XXIX.—*On the Estherville, Emmet County, Iowa, Meteorite of May 10th*, 1879; by CHARLES UPHAM SHEPARD, Emeritus Professor of Natural History in Amherst College.

FOR the circumstances attending this third fall of aerolites in the State of Iowa since the year 1847, I am indebted to a notice published in the Chicago Times by Mr. S. E. Bemis, and to letters from Mr. Howard Graves and Mr. Henry Barber of Estherville.*

The fall occurred at 5 P. M. on the 10th of May, attended by a terrible explosion, resembling the discharge of a cannon, only louder. It seemed to proceed from a region high up in mid-air; and was followed by a second report, more like a heavy blast. This again was succeeded by one or two more reports, that may have been echoes of the two first. Nearly a minute after, a rumbling sound was heard, apparently passing from the northeast to the southwest. The sky was clear at the time, or only a few fleecy clouds were visible. An observer, Mr. Charles Ega, looking in the direction of the report, could see nothing on account of the sun's rays; but following with his eye the direction of the roaring sound that succeeded, he saw dirt thrown high into the air at the edge of a ravine, one hundred rods northeast of where he was standing. At a like distance, still farther away in the same direction, a similar disturbance of the ground was seen by Mr. Barber. Another witness, Mr. S. W. Brown, living three-quarters of a mile distant, being in the edge of a wood, and having his eyes directed upward at the moment for the inspection of some oak trees, saw a red streak in the heavens; and while looking at it, the explosion took place. It appeared to him, that the meteor was passing from west to east; and that when it burst, there was a cloud at the head of the red streak, which darted out of it like smoke from a cannon's mouth, and then expanded in every direction.

On examining the ravine where a body was seen to strike, a hole in the ground was discovered, twelve feet in diameter and six in depth. It was filled with water. Within this hole, at a depth of fourteen feet below the general surface of the ground, the large mass, weighing four hundred and thirty-one pounds, was found. It had penetrated a stratum of blue clay to the depth of six feet, before its progress had been arrested. The mass measured twenty-seven inches in length, by twenty-two and three-quarters in breadth, and fifteen in thickness. Its surface is described as "fearfully rough," with ragged projections of metal. From one of these a portion was detached, and shaped into a finger-ring. After much searching, there have

* A short notice of this meteorite's fall, by Professor S. F. Peckham, is given on page 77 of this volume.—EDS.

since been found in the immediate vicinity of the hole, several smaller masses, varying in weight from one to eight ounces; also one mass of four pounds, and another of thirty-two.

At the distance of two miles from this spot, in a westerly direction, a mass of one hundred and fifty-one pounds was also discovered. It was imbedded in a dry, gravelly soil, at the depth of four and a half feet. This specimen is in the possession of the University of Minnesota at Minneapolis.

Description of the Meteorite.

The specimens thus far received (for which I am indebted to Mr. Graves), though numerous, are all small, the largest weighing only 147·7 grammes: nevertheless, accompanied as they are with a general description of the main masses, they afford the means of arriving at a tolerably clear conception of the general character of this very remarkable meteorite. It is marked by the unusual prevalence of chrysolite and meteoric iron, the former probably constituting two-thirds its bulk; also by the size and distinctness of the chrysolitic individuals, together with their pretty uniform, yellowish-gray or greenish-black color; and by the ramose or branching structure of the meteoric iron. Nearly one-half of the chrysolite, however, is more massive, approaching fine granular, or compact. Yet in this condition it is still highly crystalline, and difficultly frangible. This portion is of an ash-gray, flecked with specks of a dull greenish-yellow color. The luster is feebly shining. It is without any traces of decomposition; on the contrary, it is throughout a fresh, undecomposed crystalline aggregate. Especially is it observable, that the stony portions nowhere present traces of the oolitic, or semi-porphyritic structure, so common in meteoric stones.

The mean specific gravity of four examples of the stony portion was found to be 3·35. The crust upon this variety is of the usual thickness, black, without luster, and much wrinkled. One of the fragments shows a cavity of half an inch area, completely lined with a shining dark-green glass, as if from the perfect fusion of chrysolite.

The meteoric iron, besides being in ramose branches, is also in enveloping coatings around the chrysolite, somewhat as in the Pallas and Atacama irons. The specific gravity of this aggregate, cleared of the stony part, was 5·97; that of the large specimen of 147·7 grams, was 4·54. The presence of schreibersite in the metal is apparent to the naked eye; also traces of the Widman figures which so constantly attend its presence, and to which they owe their production.

A very remarkable appearance is exhibited by the meteoric iron in some of the specimens. It is the bright silvery whiteness of the metal where it forms a portion of the exterior of the

stone. It appears to have been fused and is surrounded on all sides by the black crust, coming from the stony material. It will be interesting to know whether this character prevails over the main mass from which these fragments were separated. If such should be the fact, it would give us a second case in which meteoric iron seen to fall, reached the earth in the possession exteriorly of a high metallic luster. The other instance is that of the Dickson County meteorite, Tennessee, July 30, 1835.

The chrysolite, in large distinct concretions and highly crystalline individuals, deserves a particular notice. Some of these show imperfect crystalline facets, and nearly all the larger ones possess eminent cleavages. In a few instances they are nearly transparent and gem-like. Specific gravity (on 0·77 grams) = 3·50.

The next most conspicuous species present is troilite. This also is in distinct individuals, sometimes as large as a pea. It is highly crystalline, rarely presenting splendent crystalline facets, whose color approaches silver-white. The proportion in which it exists is apparently large, and may equal two per cent.

Next in importance comes the feldspathic mineral, presumably anorthite. It is highly crystalline, white, lustrous and nearly transparent, resembling in these particulars the similar mineral found among the ejecta of Vesuvius.

Among the specimens are two very distinct examples of an opal-like mineral of a yellowish-brown color, which I take to be chassignite. Its luster is resinous, structure imperfectly slaty, to massive and conchoidal. A small granule of chromite occurs in one of the fragments of the massive chrysolite.

Such are the minerals thus far distinguished in the Estherville meteorite. As a whole, it differs widely from the normal meteoric stones. These differences consist, in the first place, in the unusual prevalence of a chrysolite similar to that found in the meteoric irons; secondly, in the large proportion of meteoric iron present, and in the manner in which it is involved with the chrysolite; thirdly in the fresh and highly crystalline condition of all the constituents of the meteorite. Nothing like an aggregation of pulverulent, ash-like grains, more or less rolled into oolitic shapes, so common in meteoric stones, is discernible. The stony portions much more resemble the olivinic rocks of extinct volcanos, particularly those of the Eifel district.

Judging from the specimens in hand, it cannot properly be referred to any group of meteoric stones with which we are acquainted. It would rather appear to be a connecting link between the Litholites and the Lithosiderites, though it may possibly find a place in the Eucritic group of the former, in which case it would form an order by itself.

New Haven, June 27, 1879.

IX.—*On the Color Correction of Achromatic Telescopes;* by WM. HARKNESS.

)UGH much has been written on the theory of the
ic telescope, I am not aware that any attempt has
been made to treat the color correction rigorously as
)n of the wave length of the light; and, on that
much obscurity, and some positive error, has crept
text books on the subject.
eory given in the following pages is based upon funda-
quations which neglect the thickness of the lenses, as
ys been done heretofore, and which suffice to give the
indexes to scarcely more than four places of decimals.
ubsequent operations upon these equations are rigor-
curate; and it would have been useless to attempt
recision in the refractive indexes, while the thickness
ıses is neglected. As achromatic telescopic objectives
lly composed of two lenses, rarely of three, and hardly
a greater number; it has been thought sufficient to
equations in the form applicable to triple objectives,
ifficulty will be experienced in extending them to a
umber of lenses, when necessary.
ndamental equations are

$$\frac{1}{f} = (\mu - 1)\left\{\frac{1}{r} + \frac{1}{\rho}\right\} \tag{1}$$

$$\mu = a + b\gamma^2 + c\gamma^4 \tag{2}$$

e principal focal distance of any lens.
e refractive index of the lens.
e radius of curvature of the first surface of the lens.
e radius of curvature of the second surface of the lens.
e wave length of the light.
$\div \lambda$.
= certain coefficients, determined from not less than three properly situated values of μ.
on (2) is Cauchy's dispersion formula. Now put

$$\frac{1}{r} + \frac{1}{\rho} = \mathrm{A} \tag{3}$$

ose a series of lenses, such that

$$\frac{1}{f_1} = (\mu_1 - 1)\mathrm{A}_1;\ \frac{1}{f_2} = (\mu_2 - 1)\mathrm{A}_2;\ \frac{1}{f_3} = (\mu_3 - 1)\mathrm{A}_3 \tag{4}$$

ıses being very thin, let them be placed in contact with
er; and let the equivalent focal distance of the whole

combination be f. Then, by a well known optical theorem,

$$\frac{1}{f} = (\mu_1 - 1)A_1 + (\mu_2 - 1)A_2 + (\mu_3 - 1)A_3 \qquad (5)$$

Substituting the values of μ_1, μ_2, μ_3, from equation (2), putting

$$\left.\begin{array}{l} C = A_1(a_1 - 1) + A_2(a_2 - 1) + A_3(a_3 - 1) \\ D = A_1 b_1 + A_2 b_2 + A_3 b_3 \\ E = A_1 c_1 + A_2 c_2 + A_3 c_3 \end{array}\right\} \qquad (6)$$

and arranging the terms according to the powers of γ, we have

$$f = \frac{1}{C + D\gamma^2 + E\gamma^4} \qquad (7)$$

This equation expresses the relation between the focal distance of the combination, and the wave length of the light. It shows that when white light enters an objective there will generally be an infinite number of foci, situated one behind the other, and all contained between the two values of f which correspond to the limiting values of γ. For our purpose, however, it will be more convenient to consider f as the ordinate, and γ as the abscissa, of a curve which we will designate as the focal curve. To investigate its properties, we differentiate with respect to f and γ, and obtain

$$\frac{df}{d\gamma} = -2\gamma f^2(D + 2E\gamma^2) \qquad (8)$$

Putting the left hand member of this expression equal to zero, we find

$$\gamma^2 = -\frac{D}{2E} \qquad (9)$$

Differentiating (8) a second time

$$\frac{d^2f}{d\gamma^2} = 2f^3\gamma^2(2D + 4E\gamma^2)^2 - f^2(2D + 12E\gamma^2) \qquad (10)$$

Substituting the value of γ^2 from (9), this becomes

$$\frac{d^2f}{d\gamma^2} = 4Df^2 \qquad (11)$$

which shows that, so long as D remains positive, the curve is convex toward the objective, and the value of γ given by equa- (9) corresponds to the minimum focal distance.

An achromatic objective, or more accurately, and with greater generality, a corrected objective, is one in which all rays of the kind for which the correction is made are brought to as nearly as possible the same focus. For example; if an objective is corrected for visual purposes, then the rays which produce the greatest effect upon the human eye must all be brought as nearly as possible to the same focus; or, if the objective is corrected for photographic purposes, then the rays which act

most energetically upon silver bromo-iodide must all be brought as nearly as possible to the same focus. This condition will evidently be fulfilled when the rays in question have the minimum focal distance; or in other words, when they satisfy equation (9). Thus it appears that this equation determines the correction of the objective, and for that reason it will be called the achromatic equation, and the particular value of γ which satisfies it will be designated as γ_0.

To find the relative values of A_1, A_2, A_3, in a corrected objective, we substitute in (9) the values of D and E from (6). The resulting expression for the middle lens is

$$-A_2 = \frac{A_1(b_1 + 2c_1\gamma_0^2) + A_3(b_3 + 2c_3\gamma_0^2)}{(b_2 + 2c_2\gamma_0^2)} \qquad (12)$$

which shows that this lens must be of the opposite kind from the other two,—that is, if the first and third lenses are convex, the middle one must be concave; or *vice versa.*

To find the equivalent focal distance of the whole combination for the ray λ_0, (9) gives

$$D = -2E\gamma_0^2 \qquad (13)$$

Substituting this in (7)

$$f_0 = \frac{1}{C - E\gamma_0^4} \qquad (14)$$

Replacing C and E by their values from (6)

$$f_0 = \frac{1}{A_1(a_1 - c_1\gamma_0^4 - 1) + A_2(a_2 - c_2\gamma_0^4 - 1) + A_3(a_3 - c_3\gamma_0^4 - 1)} \qquad (15)$$

Substituting the value of A_2 from (12), and putting

$$\left.\begin{aligned} n &= \frac{A_3}{A_1} \\ L &= (a_1 - 1)(b_2 + 2c_2\gamma_0^2) - (a_2 - 1)(b_1 + 2c_1\gamma_0^2) + \gamma_0^4(b_1c_2 - b_2c_1) \\ M &= (a_3 - 1)(b_2 + 2c_2\gamma_0^2) - (a_2 - 1)(b_3 + 2c_3\gamma_0^2) + \gamma_0^4(b_3c_2 - b_2c_3) \end{aligned}\right\} \qquad (16)$$

we obtain finally

$$f_0 = \frac{b_2 + 2c_2\gamma_0^2}{A_1(L + nM)} \qquad (17)$$

The ordinate of the focal curve for the ray λ_1, is the difference between the focal lengths of the objective for the rays λ_0 and λ_1. To find it we have

$$\frac{1}{f_0} - \frac{1}{f_1} = (C + D\gamma_0^2 + E\gamma_0^4) - (C + D\gamma_1^2) + E\gamma_1^4) = D(\gamma_0^2 - \gamma_1^2) + (E\gamma_0^4 - \gamma_1^4) \qquad (18)$$

But

$$\frac{1}{f_0} - \frac{1}{f_1} = \frac{f_1 - f_0}{f_0 f_1} \qquad (19)$$

and putting $f_1 - f_0 = \Delta f_1$, this becomes

$$\Delta f_1 = f_0 f_1 \left\{ \frac{1}{f_0} - \frac{1}{f_1} \right\} \qquad (20)$$

Substituting for the quantity within the brackets, its value from (18); and replacing D and E by their equivalents from (6)

$$\Delta f_1 = f_0 f_1 \{(A_1 b_1 + A_2 b_2 + A_3 b_3)(\gamma_0^2 - \gamma_1^2) + (A_1 c_1 + A_2 c_2 + A_3 c_3)(\gamma_0^4 - \gamma_1^4)\} \quad (21)$$

Substituting the values of A_2 and $A_3 \div A_1$ from (12) and (16), and putting

$$\begin{aligned} N &= b_1 c_2 - b_2 c_1 \\ P &= b_3 c_2 - b_2 c_3 \end{aligned} \quad (22)$$

we obtain the important expression

$$\Delta f_1 = A_1 f_0 f_1 (\gamma_0^2 - \gamma_1^2)^2 \frac{N + nP}{b_2 + 2c_2\gamma_0^2} \quad (23)$$

If a star is viewed through a carefully focused achromatic telescope, and if the surface in the focus of the eye-piece is designated as the focal plane: then, of the infinite number of images which equation (7) shows will be formed, some will be situated before, and some behind the focal plane, but only one will coincide exactly with it. The cones of rays which form the images situated before and behind the focal plane will necessarily have a sensible diameter at their intersection with that plane, and their combined effect will be to produce a fringe of colored light around the image of the star, as seen through the eye-piece. This fringe is the secondary spectrum, and its magnitude, for light of any given wave length, will evidently depend upon the value of Δf_1. Hence, to destroy the secondary spectrum, Δf_1 must be made equal to zero. Equation (23) shows that this will be the case for a triple objective when

$$N + nP = 0 \quad (24)$$

or for a double objective when

$$N = 0 \quad (25)$$

As yet no materials have been discovered whose physical properties are such as to satisfy these conditions. We therefore proceed to investigate what form an objective constructed of any given materials must have in order to render the secondary spectrum a minimum.

Substituting in (23) the value of A_1 from (17), we find

$$\Delta f_1 = f_1 (\gamma_0^2 - \gamma_1^2)^2 \frac{(N + nP)}{(L + nM)} \quad (26)$$

In the right hand member of this equation, n is the only quantity which depends upon the form of the objective. Considering it as variable, and differentiating, we obtain

$$\frac{d(\Delta f_1)}{dn} = f_1 (\gamma_0^2 - \gamma_1^2)^2 \frac{PL - MN}{(L + nM)^2} \quad (27)$$

To make Δf_1 a minimum, such a value must be attributed to n as will reduce the right hand member of (27) to zero. This

condition gives at once, $n=\infty$; which will be the case when r and ρ are both infinite; as is evident from equations (16) and (3). The objective is then reduced to two lenses, and a piece of very thin plano-parallel glass. As the latter cannot appreciably affect the color correction, it may be dismissed from further consideration; and thus it appears that from any three pieces of glass suitable for making an objective, but not fulfilling the conditions necessary for the complete destruction of the secondary spectrum, it will always be possible to select two pieces from which a double objective can be made that will be superior to any triple objective made from all three of the pieces.

The focal curve being tangent to the focal plane at the point corresponding to the wave length λ_0; if we assume the spherical aberration to be perfectly corrected for light of all degrees of refrangibility; then the image of a star formed upon the focal plane by light of wave length λ_0 will be a point, and the linear semi-diameter of the image of the same star formed by light of wave length λ_1 will be the semi-diameter of the cone of rays of that wave length at the point where it cuts the focal plane. Therefore we have

$$f_1 : \alpha :: \Delta f_1 : s_0^{11} \qquad (28)$$

in which α is the semi-aperture of the objective, and s_0^{11} is the required semi-diameter of the cone of rays of wave length λ_1. Combining (28) with (26), we find

$$s_0^{11} = \alpha(\gamma_0^2 - \gamma_1^2)^2 \frac{\mathrm{N}+n\mathrm{P}}{\mathrm{L}+n\mathrm{M}} \qquad (29)$$

This is the expression for a triple objective. In the case of a double one, n becomes zero, and (29) reduces to

$$s_0^{11} = \alpha(\gamma_0^2 - \gamma_1^2)^2 \frac{\mathrm{N}}{\mathrm{L}} \qquad (30)$$

which shows that in a double objective properly corrected for any given purpose, the linear semi-diameter of the secondary spectrum is absolutely independent, both of the focal length of the combination, and of the curves of its lenses; and depends solely upon the aperture of the combination, and the physical properties of the materials composing it.

If a telescope armed with an achromatic eye-piece is carefully focused upon a star, and then the image of the star is viewed through a prism held before the eye-piece; it will be seen that the eye does not adjust the focal plane tangent to the focal curve, but places it somewhat further from the objective, in such wise that the plane cuts the curve in two points, which we will designate as γ_m and γ_n. For these points we must have

$$\frac{1}{\mathrm{C}+\mathrm{D}\gamma_m^2+\mathrm{E}\gamma_m^4} = \frac{1}{\mathrm{C}+\mathrm{D}\gamma_n^2+\mathrm{E}\gamma_n^4} \qquad (31)$$

which gives

$$-\frac{D}{E}=\gamma_m^2+\gamma_n^2 \tag{32}$$

But by (9) we have

$$\gamma_0^2=-\frac{D'}{2E} \tag{33}$$

Combining this with (32), we find

$$\gamma_0^2=\tfrac{1}{2}(\gamma_m^2+\gamma_n^2) \tag{34}$$

which gives the relation between γ_0 and any pair of points at which the focal plane may cut the focal curve.

We have next to consider how the value of γ_m can be found; and for that purpose a method partly arithmetical, and partly graphical, seems most convenient. The data required are, the values of Δf for a number of different values of γ, and the relative intensity of the light at each of these values of γ. The values of Δf must be computed by means of equation (26); and the relative intensity of the light may either be determined experimentally, or taken from published tables. For visual intensity, the table given by Fraunhofer may be employed; and for photographic intensity, the curves published by Captain Abney contain all that is required. For the sake of definiteness, let us suppose that the value of γ_m is to be determined for an objective corrected for visual purposes. We begin by laying down an axis of abscissas, and graduating it into a scale of wave lengths. Here, however, it must be observed that the brightness of any part of a spectrum depends not only upon the inherent brightness of the light at that point, but also upon the degree of dispersion employed. As Fraunhofer's determinations of the relative brightness of different parts of the spectrum were made with a flint glass prism having a refractive index of 1·63 for the ray D; and as such an instrument produces much greater dispersion at the violet end of the spectrum than at the red end; it follows that our scale of wave lengths must be, not a scale of equal parts, but such a scale as existed in the spectrum employed by Fraunhofer. The wave length of the brightest ray is approximately 5688, and through that point in the scale, and at right angles to the axis of abscissas, the axis of ordinates must be drawn. Then, from the computed values of Δf, a sufficient number of points must be laid down to determine the focal curve, and that curve must be drawn. At the points whose wave lengths correspond to the principal Fraunhofer lines, lines must be drawn through the focal curve, parallel to the axis of ordinates; the length of each line being proportional to the relative brightness of the spectrum at the point where it is situated, and the center of each line coinciding accurately with the focal curve. Through

the extremities of these lines a closed curve must be drawn. The figure thus obtained will be termed the illumination diagram, because it exhibits the amount and distribution of the light at the focus of the objective. The eye will necessarily place the focal plane in the position where this light will produce the greatest effect upon the retina; which is equivalent to saying that the focal plane must pass through the center of gravity of the diagram. Hence, to find the position of the focal plane, we have only to cut out the diagram (which should be drawn upon rather stiff paper), and balance it upon a knife edge held parallel to the axis of abscissas. The reciprocals of the wave lengths of the points of intersection of the knife edge with the focal curve will then be the values of γ_m and γ_n.

The method just explained may be employed to determine the difference between the positions of the principal focus of the same telescope when used for different purposes. For example, if it were required to find the interval between the visual and photographic foci of a telescope, two illumination diagrams would be drawn—one for the visual, and the other for the photographic rays—and the difference between the positions of the focal plane in the two diagrams would be the required difference of foci.

As the magnitude of the secondary spectrum of a star is measured by the semi-diameter (at the point where it intersects the focal plane) of the cone of rays having the maximum focal distance; it follows that in an objective corrected for visual purposes, the secondary spectrum is diminished by the fact that the eye places the focal plane somewhat further from the objective than the apex of the focal curve. To find the amount of this diminution, we remark that for light of wave lengths corresponding to the points where the focal plane cuts the focal curve, the semi-diameter of the cone of rays is zero; while for light of any other wave length, the semi-diameter of the cone of rays, at the point where it intersects the focal plane, is proportional to the distance between that plane and the point of the focal curve corresponding to the wave length of the light. Hence, the effect of moving the focal plane into a position further from the objective than the apex of the focal curve, will be to diminish s_0^{11} by a constant which is numerically equal to the value of s_0^{11} for light whose wave length is that of the point at which the focal plane intersects the focal curve. Modifying equation (30) in accordance with these principles, it becomes

$$s_m^{11} = \alpha\{(\gamma_0^2 - \gamma_1^2)^2 - (\gamma_0^2 - \gamma_m^2)^2\}\frac{N}{L} \tag{35}$$

in which γ_m is the reciprocal of the wave length corresponding to either of the two points in which the focal plane cuts the

focal curve; and s_m^{11} is the semi-diameter, at the point where it cuts the focal plane, of the cone of rays whose wave length is λ_1.

The exact nature of the color correction of a telescope can be determined by placing the focal plane in a number of different positions, and observing the corresponding values of γ_m and γ_r. These values being substituted in equation (34), several independent values of γ_0 can be deduced, the mean of which will probably be very near the truth.

The conclusions reached in the preceding pages may be summed up as follows:

1st. From any three pieces of glass suitable for making a corrected objective, but not fulfilling the conditions necessary for the complete destruction of the secondary spectrum, it will always be possible to select two pieces from which a double objective can be made that will be superior to any triple objective made from all three of the pieces.

2d. The color correction of an objective is completely defined by stating the wave length of the light for which it gives the minimum focal distance.

3d. An objective is properly corrected for any given purpose when its minimum focal distance corresponds to rays of the wave length which is most efficient for that purpose. For example, in an objective corrected for visual purposes the rays which seem brightest to the human eye should have the minimum focal distance; while in an objective intended for photographic purposes the rays which act most intensely upon silver bromo-iodide should have the minimum focal distance.

4th. In double achromatic objectives the secondary spectrum (or in other words, the diameter, at its intersection with the focal plane, of the cone of rays having the maximum focal distance), is absolutely independent both of the focal length of the combination, and of the curves of its lenses; and depends solely upon the aperture of the combination, and the physical properties of the materials composing it.

5th. When the focal curve of an objective is known; and the relative intensity, for the purpose for which the objective is corrected, of light of every wave length is also known; then the exact position which the focal plane should occupy can readily be calculated.

6th. It may be remarked incidentally that in an objective corrected for photographic purposes, the interval between the maximum and minimum focal distances is less than in one corrected for visual purposes. Hence, a photographic objective has less secondary spectrum, and is better adapted to spectroscopic work, than a visual objective.

Washington, May 24, 1879.

ʟRT. XXXI.—*Terminal Moraines of the North American Ice-Sheet;* by WARREN UPHAM.

[Continued from page 92.]

BEYOND Block Island the extreme terminal moraine does ot rise above sea-level for 35 miles, at which distance in a direc-.on a little to the north of east it reäppears in No Man's Land nd Gay Head. Heights of it here and in its farther extent are s follows: No Man's Land, about 150; Gay Head, 100 to 145; bout one mile east, near the church, 185; Prospect Hill, the ighest on Martha's Vineyard, 295; Peaked Hill, a mile south om the last, 290; other hills, reaching from these five miles to ie northeast, 200 to 250; Indian Hill, 245; Sampson's Hill, n Chappaquiddick Island, about 100; highest part of Tucker-uck, about 50; Macy's or Pole Hill, the highest of Saul's [ills, 91; Folger's Hill, a mile east from the last, 88; and San-aty Head, the highest point of Nantucket Island, 105. The liffs of Gay Head, at the west end of Martha's Vineyard, expose section four-fifths of a mile long, composed at the top of the nstratified terminal moraine, five to forty feet thick, filled with bundant bowlders of all sizes up to twenty feet in diameter. 'his rests on fossiliferous beds,* probably of Miocene Age, ·hich dip from 20° to 50° northerly throughout the section, nd present a most striking succession of brightly-colored clays, ınds and gravel, varying from black to red, brown, gray and ·hite. Gay Head township, reaching three miles to the east, as a very uneven surface of glacial drift in small elevations ıd depressions, strown with frequent bowlders, but apparently nderlain by Tertiary clay and sand at no great depth.

In the next eight miles this moraine forms high parallel ınges of hills, very irregular in contour, which extend north-ıstward through Chilmark and the northwest part of Tisbury, ɔcupying a width of one to three miles. Their surface is gen-rally till, with very abundant bowlders; but occasionally, as t the top of Prospect Hill, it is modified, consisting mainly of 'ater-worn gravel and sand. The black, red and white Ter-ary clays underlie these deposits in the hills, and are exposed ı the cliffs along the northwest shore to the east side of Lum-ard's Cove, eleven miles from Gay Head. Upon the south ide of Prospect and Peaked Hills they extend to heights 225 nd 250 feet above the sea.

The southeast half of Martha's Vineyard consists of modified rift without bowlders, lying in extensive level plains, twenty-ve to fifty or sixty feet above sea. Along the south shore

* Described in Hitchcock's Geology of Massachusetts, 1833 and 1841; in Lyell's ravels in North America in 1841–2, vol. i, pp. 203–206; and in this Journal, I, ɔl. xlvi, pp. 318–320.

these plains are indented by numerous ponds, which are only separated from the ocean by a beach, and the shores of the ponds are again indented by long and narrow arms or coves, from the head of which dry channels, similar to those described on Long Island, extend across the plains in a northerly course. The road from West Tisbury to Edgartown crosses several of these depressions, one of which, known as Quampachy Hollow, may be taken as an example. This starts from the head of Oyster Pond, a narrow arm of the sea, which stretches two miles north from the beach by which it is now shut in. The dry hollow, diminishing from twenty-five to ten feet in depth, and from 300 to 100 feet in width, prolongs this valley at least three miles to the north. Near Vineyard Haven and Oak Bluffs, north of these plains, and on Chappaquiddick Island, the modified drift, sometimes sprinkled with bowlders, is heaped in gently sloping hills, 50 to 100 feet high, which appear to have been formed at the margin of the ice-sheet.

Thence the line of terminal moraine is continued in Muskeget and Gravelly Islands, which however are only low banks of gravel and sand. On Tuckernuck Island it appears again in small hills, which in part are unstratified, with plenty of bowlders, the remainder being modified drift. Nantucket is composed almost wholly of stratified gravel and sand. The line at which the ice-sheet appears to have terminated is marked in the west part of this island by gently undulating hills, forty to fifty feet high, composed of stratified drift, which, however, differs from that of the plains on the south in having here and there bowlders up to ten feet in diameter embedded in it or lying on the surface. The course of this line is from Eel Point, north of Maddequet Harbor, by Trot's Hills to the town. Eastward it continues on the same course in the Shawkemo and Saul's Hills to Sankaty Head. The portion of this series called Saul's Hills, two miles long and a half mile wide, is of very irregular contour, with steep and abruptly changing slopes, forming hills, ridges, mounds and small enclosed basins, some of which contain ponds. The material is stratified gravel and sand, upon and in which are scattered bowlders, varying up to ten feet in diameter.

Sankaty Head, at the east shore of the island, affords a section across this range.* A quarter of a mile south from the light-house, the order of deposits, beginning at the base is as follows: brown sandy clay to about twenty feet above sea; ferruginous sand and gravel, four feet; white sand, four feet; yellow sand enclosing masses of blue clay, one foot; ferruginous gravel and sand, with abundant shells, two feet; a bed of

* The Post-pliocene beds at the base of this section, and their fossils, are described by Professor A. E. Verrill and Mr. S. H. Scudder, in this Journal, III, vol. x, pp. 364–375.

serpula, mixed with sand, about two feet; gravel and sand again, thickly filled with shells, two feet; fine white sand, about ten feet; the common yellow sand and fine gravel of the modified drift, about forty-five feet, its top being at ninety feet; coarse gravel, three feet; ferruginous sand, one foot; changing above into a former surface soil, one foot thick; overlain by three feet of dune sand, which forms the present surface, ninety-eight feet above sea. The highest part of the bank is midway between this and the light-house. From a comparison of the species contained in these two shell-beds, Professor Verrill estimates that the temperature of the sea at this place was lowered 15° between the times in which they lived. The layer of coarse gravel which occurs here at the height of ninety feet, is continuous for a half-mile from this point both to the north and south, varying from three to eight feet in thickness. About half of its rock-fragments are rounded, these being of all sizes up to one foot through; the rest, which are rough and angular, range up to two feet, and rarely to four feet, in diameter. This bed has its greatest thickness and is coarsest at the highest portion of the bluff, where it closely resembles till. The old surface of black soil and the present surface of dune sand are also continuous along the same distance. An eighth of a mile south from the shell-beds, the bluff falls to a hollow about sixty feet above the sea, and in this depression the blackened layer becomes a bed of peat, two feet thick, containing numerous stumps and roots of trees and covered by two feet of sand. The rocky stratum, the old surface soil, and the overlying sand thus cap the bluff for more than a mile, in which its height falls from 105 feet at the middle to about 35 feet at each end. Below the rocky layer it consists of fine modified drift and pre-glacial beds. This succession tells of a period when the sea had about its present temperature; next it becomes much colder: sand and fine gravel are accumulated to a depth of more than fifty feet, probably brought by rivers from the summer-meltings of the ice-sheet; this finally reached its outmost limit, overspreading the north half of the island; at its retreat the coarser materials which it held were dropped; forests sprang up, as the climate became mild again; and, lastly, the sea has eaten away the east portion of these deposits, while the sand of its shore has been swept by the wind over their top.

The whole south side of Nantucket Island consists of nearly level plains of gravel and sand, twenty to sixty feet above the sea. This expanse, reaching more than ten miles from west to east, with a width varying from one to three miles, is broken by frequent hollows which extend approximately from north to south, like those already noticed on the similar plains of Long

Island and Martha's Vineyard. Narrow ponds, to the number of a dozen or more, having the same height with the ocean, fill the entire course of these depressions, or occupy their lower end next to the south shore.

The Second Terminal Moraine.—A later series of morainic hills extends along the north shore of Long Island for forty-five miles eastward from Port Jefferson to its extremity at Orient Point. Their heights are approximately as follows: Strong's Neck, close east of Port Jefferson, 100 to 200 feet; Mount Sinai, at school-house, and Miller's Place, each about 150; Noah Jones' Hill, 1½ miles east from Miller's Place, 200; Pine Hill, one mile farther east, 175; Blue Point Hills, one mile southeast from last, 150; hills near Wading River village, 150 to 200, the highest of which, at Mr. D. M. Tuthill's, a mile east from the village, commands a very fine view; hills, partly of dune sand, north of Baiting Hollow, known by the names of "Horse in the Bank," Horton's Bluff, and Friar's Head, about 150; at Northville, 125; Jacob's, Cooper's and Mattituck Hills, 125 to 150; Manor Hills, extending east from Mattituck Inlet, 100 to 150; Horton's Point, 70; highest points for the next seven miles, extending by Greenport, about 50; Brown's Hills, north of Orient, 110 and 160. East from the light-house on Horton's Point, these deposits, though not rising in prominent hills except at Orient, are in many places unstratified, with an abundance of large angular bowlders, which are of all sizes up to twenty-five feet in diameter. This terminal moraine overlies stratified gravel, sand and clay, which contain no bowlders; as is well shown in the bluffs, 50 to 100 feet high at the north side of Brown's Hills, where the very coarse morainic till is five to twenty feet thick, and forms the entire surface of these hills. The last two miles of this shore from near Brown's Point east to Orient Point, are all stratified gravel and sand twenty to forty feet high, strown in only a few places with bowlders; being a part of the plains which skirt the south side of the moraine. Its hills probably once existed here at a little farther north, but they have been washed away by the sea. The same action is apparent throughout the whole extent of this series on Long Island, so that many of these hills have lost more or less from their north side, and stand as half-eroded barriers which are still falling slowly before the encroachment of the waves. The greater portion of this series, extending more than thirty miles from Port Jefferson to Horton's Point, is composed, like the extreme moraine on the south, of obliquely stratified sand and coarse gravel, with occasional bowlders, which are sometimes of enormous size. One of these, about thirty feet long, lies at the north side of the road, 1½ miles west from Wading River. Two

others of equal size are seen close to the road in Setauket village. The largest block yet found on Long Island lies much farther west, at about a mile southeast from Manhassett, and is, according to measurement by Mr. Lewis, fifty-four feet long, forty feet wide, and sixteen feet high.

This later moraine is separated six to ten miles, on Long Island, from that formed at the extreme line reached by the ice-sheet, and the area between them is occupied by extensive plains, the Peconic Bays, and Shelter Island. This series of plains resembles that of southern Long Island, in that both slope southward from terminal moraines on their north side, and are alike crossed by ancient water-courses which are now dry. The plains associated with the second terminal moraine begin at Syosset, about twenty-five miles west from Port Jefferson, and it is not improbable that the second moraine may be represented in the irregularly scattered hills, composed of modified drift with bowlders here and there, which lie at their north side along this distance. For the first ten miles the plains vary from one to two or three miles in width, having a height from 100 to about 150 feet above sea. Their greatest altitude appears to be at East Northport station. Here they pass beyond the north spur of the Dix Hills and expand to the south, attaining a width of five miles, which continues without much variation to Riverhead. In Smithtown considerable portions of these plains have been removed by the erosion of streams since the Glacial period. Their height along their north side here and in Brookhaven is 150 to 100 feet above sea, from which the general slope southward is about ten feet to the mile. Near the east line of Brookhaven is a notable series of ponds, reaching four miles, and lying in depressions of one of the old lines of drainage. These are called the West Row Ponds, and are known in their order from north to south as Long Pond, Big and Little Tar-kiln, Pease's, Duck, Sandy, Grass, and Jones' Ponds, extending to the Peconic River at a mile west from Manorville. Two miles eastward in Riverhead are the East Row Ponds, a similar series, including in the same order the two Jackson Ponds, Ice, Worthington and Fox Ponds. Northeast from Fox Pond is a tributary series, including Sand, Mud and Cranberry Ponds. Several other valleys, not containing ponds and of similar character with those of the southern plains, extend southward from the vicinity of Baiting Hollow and Northville. On the north branch of the island these plains diminish from four miles to about one mile in width, their height being sixty to thirty feet at the north, from which they slope to the shores of Peconic and Gardiner's Bays. The hilly character of Shelter Island, which varies from 50 to about 180 feet in height, being composed of stratified sand and gravel

with occasional bowlders, indicates that it was of similar origin with the hills of modified drift in the two moraines between which it lies. During the retreat of the ice-sheet it would appear that exceptionally large deposits were accumulated by its rivers here and at Gardiner's Island.

The continuation of the second moraine beyond Orient Point is to the east-northeast in Plum and Fisher's Islands, and from Watch Hill through the south part of Westerly, Charlestown and South Kingstown in Rhode Island, to near Point Judith. On Plum Island it forms hills about 100 feet high, abundantly covered with bowlders; but a considerable tract on the south side of this island is a low plain of modified drift, free from bowlders and sloping southward. Gull Island is a remnant of this plain which was formed in front of the terminal moraine. Fisher's Island, about seven miles long, is a conspicuous remnant of the moraine, being composed of the same coarse glacial drift with Brown's Hills and Plum Island. Its elevations vary from 100 to nearly 200 feet in height, the most prominent being Mount Prospect, North Hill, and Chocomount. Portions of the low plains are preserved on its south side for a mile from its west end, and again for a third of a mile between two ponds near the middle of the island.

In the State of Rhode Island this moraine is well developed for seventeen miles, and its whole course may be finely seen from the carriage road in going from Watch Hill through Charlestown and Perryville to Wakefield. After the first three miles, which are mostly on the north side of the range, this road lies for fifteen miles at the south foot of these hills, which are so irregular and broken in contour and so rough with their profusion of bowlders that they cannot fail to impress the observer with the remarkable features of an entirely unmodified terminal moraine. The width of this series of deposits is from one to two miles, and some of its highest points, not noticeable from this road, consist of stratified gravel and sand without bowlders. Such are Chin and Cranberry Hills in Westerly, and the tops of Indian Burying and Sand Hills in Charlestown. These rise 100 to 150 feet above sea, and probably no points of the range reach to 200 feet. Fort and Village Hills in Westerly, the "Old Mountain" and Bunker Hill in Charlestown, and Broad Hills in South Kingstown, are unmodified portions of this series. The margin of land on its south side, averaging perhaps a mile in width, consists mainly of gently undulating modified drift, with occasional bowlders, its only expanse in plains being for about three miles in the southeast part of Charlestown. Within one to two miles northeast and east from Perryville, several ponds occur among the hills, ridges and knolls of the moraine. At this part of its

ourse it appears to turn to the southeast, passing into the sea wo miles west of Point Judith. This angle corresponds to a imilar one which was probably formed in the extreme moraine t Block Island, whence it also seems to have extended first to he southeast, in which direction very rocky fishing-ground is ound at a distance of ten miles from that island.

The next appearance of the northern moraine is in the Elizaeth Islands, where the position of Cuttyhunk, Penikese and Vashawena Islands corresponds to that of No Man's Land, Gay Iead and the hills of Chilmark in the southern moraine, indiating that angles occur again in them both, respectively at Penikese and at Gay Head. Heights of the later moraine on he Elizabeth Islands and Cape Cod, are as follows: highest ortion of Penikese, about 100 feet; of Cuttyhunk, Nashavena, Pasque and Naushon Islands, about 175; the Quisset Iills, west of Falmouth village, about 150; station of the Unied States Coast Survey, a mile east of West Falmouth, 198; he Ridge Hills, extending thence to the angle of this series iear North Sandwich, 150 to 200 feet; southwest from Sandrich village, about 225; Bourne's Hill, a Coast Survey station, wo miles south-southeast from Sandwich, the highest point of he whole series, 297; the Discovery Hills, including the last nd extending eastward, 250 to 150; Shoot Flying Hill in Barnstable, about 200; German's Hill in Yarmouth, 138; Scargo Hill in Dennis, 166; railroad summit at Brewster staion, 125; and Mill Hill in Orleans, about 150.

This moraine forms the entire chain of the Elizabeth Islands, ifteen miles long, with an average width of one mile. Their ontour throughout is very irregular in roughly-outlined hills nd ridges of variable height, enclosing many crooked and owl-shaped hollows, which often hold small ponds. Their naterial is glacial drift with abundant bowlders of all sizes up o twenty or thirty feet in diameter. The surface exhibits all he characteristic features of the upper till, being loose, yellowsh in the color of its detritus, and with its bowlders almost nvariably angular. This deposit also appears to form the greater part of the cliffs upon the shores of these islands. At he northeast end of Naushon, however, in deepening an old vell from forty-five to sixty-seven feet, only the dark and comact lower till, or ground-moraine, was found.

The trend of this chain of islands is about east-northeast, but n the peninsula of Cape Cod the same belt of hills, continuing rith its width, contour and material unchanged, bends within few miles to a course nearly due north. A railroad cutting hirty feet deep in these deposits near Wood's Hole, and shalower sections on the Quisset Hills, show two or three feet of ellowish till at top succeeded below by light gray till, equally

coarse but apparently more compact, with some of its fragments planed and striated. The latter was probably accumulated beneath the ice-margin, while the former was dropped by its melting. After holding its way northward ten or twelve miles, reaching to a point about a mile south of North Sandwich, the range turns at a right angle to a course a few degrees south of east. Some portions of it in this vicinity are strown with bowlders, but mainly, as shown on the roads which cross these hills southwest and south from Sandwich village, at the highest portion of the entire series, they consist of stratified gravel and sand, with bowlders rare or entirely wanting. There is also a change to a more simple contour, with fewer irregular hills and hollows. From its angle the range extends about thirty-five miles to the east shore of the cape. Through Sandwich and Barnstable it lies about a mile south of the railroad, consisting in the latter town of hills 100 to 200 feet high, apparently formed of modified drift, with frequent bowlders embedded in it and scattered upon its surface. In Yarmouth the series is somewhat broken, and the railroad crosses it upon a sand plain a little west of German's Hill. South of Dennis Pond and for one and a half miles northeast from German's Hill to Follin's Pond, it is very well shown in exceedingly rocky, low hills. Next it appears to suffer an offset of about two miles to the north, being represented by Scargo Hill, which is modified drift with only few bowlders. Thence it runs a little north of east six miles to Brewster station, where it is again crossed by the railroad. Through most of this distance it is very rocky, some of its blocks being twenty to thirty feet or more in diameter. Its further course is mostly modified drift with occasional bowlders, passing east-northeast to Mill Hill, Orleans village, and the southeast side of Town Cove, beyond which it is concealed beneath the ocean.

The angle of this range at North Sandwich shows that the portion of the ice-sheet on the west and that on the east pushed against each other here, the motion and slope of each being directed toward its line of frontal moraine. The medial moraine produced where their slopes came together north from the angle of their terminal line, is presented in Rocky, Manomet and Pine Hills, which form a gigantic ridge in the east part of Plymouth, four miles long from north to south, with a continuous height 300 to 400 feet above the sea. Abundant angular bowlders of all sizes up to twenty feet in diameter strow its surface. At the north end of this ridge the sea has undermined its base, forming a steep slope sixty feet in height. A section here showed twenty feet of upper till, yellowish, with abundant large and small bowlders, nearly all of them angular, underlain by lower till, dark bluish gray, with small glaciated

tones, exposed for twenty feet vertically but concealed below. The bed of bowlders which forms the shore at this point came mostly from the upper stratum, and their sharp corners and edges have since been worn away by the waves.

On Cape Cod, as on Long Island, Martha's Vineyard and Nantucket, we find south of the line of morainic hills an area of stratified gravel and sand without bowlders, forming extensive plains which slope very gently southward. These are fully ten miles wide from north to south in Sandwich, Falmouth and Mashpee, and thence to the east they have an average width of five miles. From the southwest limit of this area at Falmouth village, the traveler who follows the road along the south side of the cape for thirty miles sees only level plains, twenty-five to forty feet above the sea, with occasional hollows and valleys, most of which are occupied by ponds and brooks. The north edge of this area, next to the terminal moraine, consists of more elevated plateaus, 50 or 75 to 200 feet in height. From this line there is a continuous slope southward, scarcely perceptible, but declining in the five to ten miles of its extent to within twenty-five to forty feet above sea. This north portion of the plains is marked by frequent hollows of large extent, which contain ponds 50 to 100 feet below the general surface. A fine idea of the slope of this deposit of modified drift is obtained in a journey from Sandwich to Greenville, Ashunet Pond and Falmouth. The ascent of 200 feet or more from sea-level to the highest point of the road is accomplished in two miles, bringing us to a point where Bourne's Hill, the highest on Cape Cod, is within a half mile to the east; while close at the west is the Great Hollow, about 100 feet deep and perhaps a half-mile wide, enclosed on all sides by the hills and high plains. Without descending more than twenty feet below its highest point, the road next enters on a plain of gravel and sand, and thence extends seven miles before crossing the first hollow which is at Ashunet Pond. Beyond this point it crosses numerous depressions that are or have been water-courses; but there is no break in the continuity of the plains, which in about twelve miles descend by a gradual slope from the height of 200 feet to sea-level.

These plains of Cape Cod are also like those previously described in being indented by narrow arms of the sea which reach one to two miles inland, filling the lower end of long depressions that continue across the plains to the north, being either dry or occupied by small streams. These channels are best shown on Cape Cod in Falmouth and eastward to Cotuit harbor, being in the region directly south from the angle of the terminal moraine and from its highest hills, which in this portion of its course are composed mainly of modified drift;

in other words, they occur most abundantly where the drainage from the melting ice-sheet must have been greatest, including all the floods poured down from the ice-fields along the line between Falmouth village and North Sandwich, those that converged toward the angle of the ice-margin, and those which brought down its vast frontal hills of gravel and sand along several miles eastward.

Extensive portions of the terminal moraines were deposited, as we have seen, by rivers which flowed from the surface of the melting ice when a warmer climate returned. On the south side of these the plains have their greatest width and height, while on the north we also find extended areas of modified drift, which show that the glacial floods continued to be poured down to the same portions of the ice-margin during its retreat. Thus on Long Island the area north of the extensive moraine from the Narrows to Roslyn consists almost wholly of undulating unmodified drift with abundant bowlders, while farther eastward it is stratified gravel and sand with few bowlders. Wherever angles occurred in the terminal front of the ice its surface had converging slopes, which would be likely to produce extraordinary fluvial deposits. This may explain the origin of the thick beds of stratified drift which form nearly the whole of Block Island, and of the plains in South Kingstown, R. I., which extend six miles north from the angle of the second moraine, reaching from Tucker's and Worden's Ponds to the north line of the township. The plains south of the moraines at their angles near Vineyard Haven and North Sandwich are notably due to the debouchure of glacial rivers at these points; and when the ice-sheet retreated from its second moraine, the floods which it discharged formed a most irregular belt of gravel and sand in ridges, hills, plateaus and hollows of every shape, but generally with a north-to-south trend, through a distance of nearly twenty miles to the north and north-northwest, reaching from its angle at North Sandwich through Plymouth to Kingston. West and north from these kames, the greater part of Plymouth County consists of nearly level or moderately undulating deposits of modified drift, 50 to 150 feet above sea, which reach continuously from the angle of the terminal moraine on Cape Cod more than thirty-five miles to Hingham, on the south shore of Massachusetts Bay. Another and perhaps more remarkable series of fluvial deposits was supplied from the melting ice-sheet to form Nantucket, the hills which rise 75 to 125 feet above sea in Chatham, the southeast township of Cape Cod, and the north portion of this peninsula beyond Orleans, which consists entirely of modified drift from 50 to 175 feet above sea.

The first recognition of the terminal moraines of southeastern

Massachusetts was by Mr. Clarence King,* who examined Naushon Island and pronounced it, with the similar formation continuing on Cape Cod, to be a series of deposits accumulated at the margin of the continental ice-sheet. The same conclusion has been announced by the geologists of Wisconsin and New Jersey respecting the series which cross those States. At these lines the border of the ice appears to have remained nearly stationary through a long period, in which the materials that it contained were being continually brought forward and deposited.† In many places these would be pushed into very irregular heaps and ridges by slight retreats and advances of the ice-margin. At the same time we should also expect that thick beds of ground-moraine would be gathered beneath the ice near its termination. The withdrawal of the glacial sheet would then leave these deposits as upper and lower till, one overlying the other in a long but broken and undulating range. In many parts of these series, however, the materials brought by the ice have been covered by modified drift brought by glacial rivers; so that the three divisions of the drift join to form the terminal moraines. No similar series of drift deposits seems to have been discovered north of the second here described, and we may conclude that in general the retreat of the ice-sheet did not admit sufficient pauses for their formation.

* Proceedings of the Boston Society of Natural History, vol. xix, p. 62.

† In Long Island and throughout New England, the materials that make up the drift are uniformly derived from the north, the greater part of them being from the nearest formations in that direction, while nearly all the rock-fragments are represented by ledges within fifty miles. The most remote origin required by any bowlders or pebbles found in the drift of New Hampshire during the recent geological survey of that State is about eighty-five miles. Respecting the origin of bowlders at the north end of Manomet Hill in Plymouth, Dr. Edward Hitchcock, the State Geologist, reported that this locality shows nearly every variety of granite. syenite and porphyry, found along the coast northward as far as the extremity of Cape Ann. Dr. C. T. Jackson, in his report on the geology of Rhode Island, says that the greater part of the bowlders found on Block Island are porphyritic granite such as occurs in place at Point Judith and Kingston, twelve and twenty miles distant at the north. Sir Charles Lyell, in his "Travels in North America," quoting in substance from one of Professor Mather's annual reports, says of Long Island: "At its eastern extremity the bowlders are of such kinds of granite, gneiss, mica slate, greenstone and syenite, as may have come across the Sound from parts of Rhode Island, immediately to the north. Farther westward, opposite the mouth of the Connecticut River, they are of such varieties of gneiss and hornblende slate as correspond with the rocks of the region through which that river passes. Still farther west, or opposite New Haven, they consist of red sandstone and conglomerate, and the trap of that country; and lastly, at the western end, adjoining the city of New York, we find serpentine, red sandstone, and various granitic and crystalline rocks, which have come from the district lying immediately to the north."

Excepting the pre-glacial deposits which have been mentioned, and a small area of gneiss and hornblende schist at Long Island City and Astoria, the whole of Long Island, Block Island, Martha's Vineyard, Nantucket, the Elizabeth Islands, and the peninsula of Cape Cod, consist of drift deposits which owe their accumulation, as has been here shown, to the action of the ice-sheet and its rivers in amassing them at its termination.

It remains for us to notice briefly the probable extent and equivalency of these terminal accumulations of the ice-sheet, both to the east and west. Agassiz believed that the fishing banks or submarine table-lands, which lie at a distance of 100 to 200 miles east and southeast from Cape Cod, Nova Scotia and Newfoundland, are such glacial deposits. On the other hand, it has been recently learned that fragments of fossiliferous rock,* apparently of Miocene age, are brought up from the sea-bottom on George's Bank, Banquereau and the Grand Bank, by the coralline growths attached to them becoming entangled with fishermen's lines. These indicate that this coast, 1,000 miles in extent, is bordered by submerged Tertiary formations, similar to those that occur above sea-level in the Southern States, as had been already suggested by Professor C. H. Hitchcock,† before this discovery. Although it now seems likely that these older deposits form the principal basis of the fishing banks, it is clear that the opinion of Agassiz was part of the truth; for besides the fossiliferous fragments many of granites and schists are also obtained by the fishermen. Furthermore, the course of the extreme terminal moraine that crosses New Jersey, Long Island, Block Island, Martha's Vineyard and Nantucket, has its line of continuation in these remarkable submarine banks. It is probable, therefore, that they consist, somewhat like Gay Head, of Tertiary strata covered with their own and foreign detritus brought by the ice-sheet.

The later moraine of Cape Cod, the Elizabeth Islands, southern Rhode Island and the north shore of Long Island, was formed after the ice had retreated from its farthest limit, but while it still terminated eastward beyond the present coast-line. This halt in its departure was extended along the entire margin of these ice-fields to the west for a distance of more than 2,000 miles. In the interior of the United States the extreme limit of glacial action has not yet been found to be generally marked by extraordinary deposits, but a most notable series of terminal moraines north of this line and probably contemporaneous with that of Cape Cod is found, as recently shown by Professor Chamberlin,‡ stretching across Ohio, and represented in southern Michigan, in the Kettle Moraine of Wisconsin, and the Leaf Hills of Minnesota; while its farther continuation seems to be in the Coteau des Prairies and the Coteau de Missouri of Dakota and British America, reaching northwestward, according to Mr. G. M. Dawson,§ to the North Saskatchewan

* Described by Professor Verrill in this Journal, III, vol. xvi, p. 323.

† Appalachia, vol. i, p. 13; and Geology of New Hampshire, vol. ii, p. 21.

‡ "On the Extent and Significance of the Wisconsin Kettle Moraine," in Transactions of Wisconsin Academy of Science. 1878, with maps.

§ Quarterly Journal of Geological Society, vol. xxxi, pp. 614–623, with map.

River, 350 miles west of Winnipeg Lake. These deposits, like the moraines of southern New England, are made up entirely of drift materials, partly unstratified with abundant bowlders and partly stratified gravel and sand, in hills 100 to 300 feet high, of very irregular contour, with many enclosed hollows, and occupying a width of from one to thirty miles. They lie upon the uneven surface of the rocky strata, being continuous across valleys and ranges of highland, which in Wisconsin undulate 800 feet in vertical height; while the elevation of this entire series of terminal moraine varies from sea-level in the region that has been here described to 2,000 feet above it at the north line of Dakota.

In the Western States the front of the ice-sheet is shown by Professor Chamberlin to have been lobed, producing acute angles in its terminal moraine, with medial moraines extending northward from them; corresponding to which, we find a deflection of ninety degrees in the series of morainic hills on Cape Cod, with the massive medial moraine of Manomet and Pine Hills a few miles farther north. The same lobed character appears also to have marked the ice-sheet at its greatest extent, making angles similar to those of a later period in its frontal line, and even enclosing a large driftless area in Wisconsin. It is now possible to draw two pictures in our mind of this glacial sheet: the first, when it reached its farthest boundary, probably coinciding nearly with the course of the Columbia, Missouri and Ohio Rivers, and the south coast of New England, while a part of Wisconsin and adjacent States was an oasis of verdure surrounded by its desert of ice; the second, when it had yielded a portion of its ground, but rallied again to a sturdy resistance before being fully put to flight.

ART. XXXII.—*New Observations on Planetoids;* by C. H. F. PETERS. (Communication to the Editors, dated Litchfield Observatory of Hamilton College, Clinton, N. Y., August 10, 1879.)

I TAKE pleasure in communicating the following planet observations:

(77) *Frigga.*

1879.	Ham. Coll. m. t.	α. app.	δ. app.	(log. p.′Δ.)		No. comp.
July 17.	14h 39m 5s	21h 32m 7s·38	−17° 44′ 43″·9	0·168	0·884	11
" 19.	12 51 10	30 48·57	17 51 1·7	$0·160_n$	0·884	10
" 20.	11 14 52	30 8·64	17 54 9 9	$0·372_n$	0·880	10
" 21.	13 6 3	29 21·22	17 57 51·4	$9·853_n$	0·873	12
" 24.	10 14 32	27 9·46	18 7 49·8	$0·688_n$	0·853	10
" 28.	13 19 5	23 47·04	18 22 51·7	9·804	0·889	5
Aug. 9.	12 9 18	21 13 2·44	−19 5 48·2	9·453	0·892	10

(200) [discovered July 27.]

1879.	Ham. Coll. m. t.	α. app.	δ. app.	(log. p.″Δ.)		No. comp.
July 27.	$14^h51^m44^s$	$21^h42^m46^s{\cdot}78$	−15°37′58″·8	0·417	0·869	10
" 28.	14 15 31	41 59·83	15 39 36·7	0·239	0·874	10
" 30.	13 55 43	40 21·57	15 42 59·5	0·159	0·875	10
Aug. 9.	11 21 41	21 31 30·22	−16 0 45·3	$0{\cdot}218_n$	0·876	10

To the planet (199), found on July 9th, as mentioned in the last number of the Journal, I have given the name *Byblis.*

Frigga, as is known, had been searched for in vain for many years, though it had come twelve times in opposition since its discovery, Nov. 12, 1862. There existed nine observations of it made by myself at its first apparition, distributed over ninety-four days; further, three observations, made by Professor Tietjen in April, 1864, after opposition, and one by the same on January 21, 1868, which, however, Professor Tietjen later has doubted, that it perhaps was another object. From the fact, that in at least three of the oppositions I have searched with carefully prepared charts without finding any trace of the planet, I am led to suspect some kind of variability of light-reflecting power, be it atmospheric or arising from the shape. And I find, that, in communicating my observations in 1863 to the Astron. Nachr. (No. 1423), I added then the following note: "From the mean of the estimates the magnitude of the planet in the *mean* opposition results 13·0. Remarkable is the whiteness of the light with which it was shining, and though but a luminous point, the image presented a certain neatness. This was very striking in comparing it on the same evenings, therefore independently of the state of the air, with Feronia, which was not far off." Moreover, in 1864 Professor Tietjen, as he orally communicated to me, estimated the magnitude much larger than the computation had given it. Frigga, therefore, needs watching, as perhaps it may give us some insight into the physical structure of the planetoids and their atmospheres.

When it was re-discovered, on July 16th, its position differed about 6° in right-ascension and 2° in declination from the place rigorously computed with regard to perturbations, etc. The motion ascertained and the situation in the orbit plane, however, made at once probable the identity. For making more sure of this, I computed from the observations of July 17th and 20th a circular orbit, which gave

$$\Omega = 4°\ 5', \qquad i = 2°\ 23', \qquad \log a = 0{\cdot}4425,$$

while for Frigga we have

$$\Omega = 2°\ 1', \qquad i = 2°\ 28', \qquad \log r = 0{\cdot}431,$$

therefore quite the same, the apparently larger difference in the longitude of the node arising only from the small inclination.

Art. XXXIII.—*Observations on the genus* Macropis; by W. H. Patton.

Hermann Müller found the females of the European *Macropis labiata* Panz. upon the flowers of *Lysimachia vulgaris* only, while the males occurred also upon the flowers of *Oenanthe fistulosa*, *Rhamnus frangula*, and *Rubus fruticosus*.* This is the basis upon which Sir John Lubbock has made and repeated the statement, that "the species visits exclusively *Lysimachia vulgaris*."† Yet Dufour had previously taken both sexes upon *Alisma Plantago*, and Schenck had taken either one or both sexes upon *Bryonia*, *Rubus cæsius*, *Cirsium arvense* and *Picris*. Subsequently, Mr. John B. Bridgman has taken the male upon *Cirsium arvense*,‡ and upon *Lysimachia*, Mint and Marsh Potentilla, and the female upon *Cirsium arvense* and *Lysimachia*.§ I have taken the female of the American species upon *Lysimachia ciliata*,‖ *Rhus glabra* and *R. typhina*, and *Archangelica hirsuta;* and the male upon *Rubus villosus* and *Cornus paniculata*.

Yet there appears to be some peculiar relationship between the *Macropis* and the *Lysimachia*. Collecting in 1874 and 1875, I observed that the *females taken upon other flowers had no pollen masses* upon their legs, and were indeed upon another quest. Mr. Bridgman (l. c., 1878, p. 22) observed that the females taken on *Cirsium arvense* had no pollen. Can it be that the young live upon the pollen of *Lysimachia* only, just as other insects are restricted to the foliage of particular plants?

Hermann Müller (l. c., p. 248), observing that the pollen was collected upon the tibiæ of these bees in thick *moist* balls, and unable to find any honey in the flowers of *Lysimachia vulgaris*, was led to believe that the bees pierced the cellular tissue of the flowers with the *ligula* for the juices with which to moisten the pollen. This act of the bee seems to me both impossible and unnecessary. The ligula is too weak, and, if we are to look to the *Lysimachia* for a solution of the problem, it is well

* Die Befruchtung der Blumen durch Insecten, pp. 348 and 463 (1873).

† Belfast Address, 1874; Nature, vol. x, p. 425, and British Wild Flowers in Relation to Insects, p. 21. The inconsistency of his statement appears when he says (British Wild Flowers, p. 126) that "*Lysimachia vulgaris* produces no honey," and the question arises in the mind of the reader: where do the bees get the honey upon which they must live?

‡ Newman's Entomologist, Aug., 1876, p. 158.

§ Ibid., Jan., 1878, vol. xi, p. 22.

‖ The group of Lysimachias containing *L. ciliata* has recently been set apart as a distinct genus, *Steironema* Raf., by Professor Gray (Proc. Am. Acad., vol. xii, p. 62) because of differences in the æstivation of the corolla, but for our present purposes, *Tridynia* (containing *stricta* and *quadrifolia*), *Lysimachia* (containing *vulgaris*) and *Steironema* may be treated together under the name *Lysimachia*.

to ask whether the glands with which the filaments and base of the corolla are beset may not furnish the nectar. In the American *L. ciliata*, *L. quadrifolia* and *L. stricta*, and on the filaments at least of the European *L. vulgaris* the glands are very numerous. But upon the flowers of *stricta* and *quadrifolia* the *Macropis* has not yet been found, although the flowers have been often watched; it seems, therefore, that the glands afford no attraction. We must conclude that it is with nectar that the pollen is moistened; and as it has been my good fortune to distinctly observe a female *Macropis* sucking nectar from the flowers of *Rhus glabra*, it is, evidently, from these and other flowers that the *Macropis* obtains the honey for the food both of itself and its young.

But why does the *Macropis* moisten the pollen as it is collected? This is an unusual habit. The social bees moisten it in order that it may be retained on the pollen plates. The Scopulipede and Gastrilege bees retain the dry pollen with the hairs forming the pollen brushes. The *Lysimachia* pollen is not of so dry a nature that hairs would not hold it. An altogether new interest was given to the genus *Macropis* by Hermann Müller's observation that it alone of all the solitary bees of Germany moistened the pollen as collected, thus economizing in the expanse of hairs upon the legs.* The retaining hairs upon the posterior legs of *Macropis* are unusually short. By moistening the pollen they are enabled to retain much larger masses than they otherwise could. Such, also, is the habit, as I have observed, with the allied American genera *Scrapter*, *Calliopsis*, and *Perdita* (*P.* 8-*maculata* Say); and Fritz Müller has recorded the same habit for *Centris*, *Tetrapedia* and *Epicharis* in Brazil,† although in these latter genera the scopa is long.

On account of the close resemblance which *Macropis* bears to the higher bees, Shuckard (British Bees) was led to believe that it would be found to agree with them in their noisy flight also. But repeated observations in the field, under the most favorable circumstances, have satisfied me that their flight is perfectly silent. Yet Shuckard is not correct when he says the other *Andrenidæ* are mute, for I have observed that certain species of *Colletes*, *C. armata* mihi and *C. compacta* Cress., and possibly, some of the larger species of *Andrena*, make, during flight, a distinct hum much like that of the honey-bee.

* L. c., p. 47, and Anw. d. Darw. Lehre auf Bienen, p. 22 (1872).

† Nature, vol. x, p. 103. These observations by Fritz Müller are open to doubt. In *Centris*, as in our native genera *Diadasia* (n. g.) and *Melissodes*, the hairs of the scopa are conspicuously plumose, and the pollen would have a matted appearance even when dry. It can be stated with confidence that, even if the pollen is slightly moistened by these bees, it is not formed into a paste, as it is by the social bees.

Up to the present time no French* or English author has questioned the validity and naturalness of the two groups, *Abeille* and *Pro-abeille*, into which Réaumur divided all the bees. Kirby adopted this classification, employing the names *Apis* and *Melitta;* Latreille adopted it under the names *Apiariæ* and *Andrenetæ;* and all subsequent authors have employed the same classification, either under these names or under Leach's family names *Apidæ* and *Andrenidæ*. Yet the only characters given for separating the *Apidæ* and *Andrenidæ* which are not entirely erroneous are:

Apidæ; labium longer than mentum, basal joints of labial palpi elongate, labium slender and not flattened.

Andrenidæ; labium shorter than mentum, basal joints of labial palpi not unlike the following joints, labium flattened.

But in the genus *Scrapter* (placed among the *Andrenidæ*) the palpi are precisely as in *Calliopsis* (placed among the *Apidæ*), and, as I have observed, the labium in repose is of precisely the same length—in both extending to the tip of the basal joint of the palpi. The greater breadth of the labium in *Scrapter* can alone determine to which family it belongs, and this difference in breadth is imaginary rather than real. Moreover, in the genera *Megalopta* and *Oxystoglossa*, and some groups of the genus *Nomia* (genera placed among the *Andrenidæ*), the labium is as slender as in the *Apidæ;* and in the genus *Hyleoides* (placed among the *Andrenidæ*) the joints of the labial palpi are proportioned just as in certain of the *Apidæ*.

Rejecting, therefore, the families *Andrenidæ* and *Apidæ*, and without proposing, at present, a more natural classification for the ANTHOPHILA, *Macropis* may be removed from connection with the short-tongued bees and placed between the *Andrenoides* and *Scopulipedes*. In the greater number of its characters it is allied to the *Andrenoides*, but in single characters of great value it bears relationship to other very diverse groups. With the *Andrenoides* it agrees in the venation of the anterior wings, which differs from that of *Scrapter* and *Calliopsis* in the pointed marginal cell only, in the cleft claws of the female, and in the habit of moistening the pollen as collected. With *Andrena* it agrees in the form of the tongue and palpi. With the *Scopulipedes* it agrees in the short anal lobe of the posterior wings and in general appearance. In the form of the basal joint of the posterior tarsi of the female it agrees with none but the social bees, which also have the habit of moistening the pollen as collected.

* As Lepeletier failed to recognize the *Bees* as a natural group, he cannot be said to have presented any classification of them.

MACROPIS PANZ. (1809).

Ocelli in a slight curve; face slightly narrowed beneath; clypens not elevated, yellow in the male; labium transverse, entire; mandibles stout, obtusely bidentate; maxillary palpi 6-jointed, the sixth and one-half of the fifth joints extending beyond the apical lobe of the maxillæ; labium lanceolate, one-third the length of the mentum, the latter narrowing toward the base, the paraglossæ small; joints of the labial palpi decreasing in length successively, the basal joint equal in length to the second and third taken together. The flagellum in the female sub-clavate, the first joint ovate, the second narrowed toward the base and one-third longer than the first joint, the third and fourth joints equal and when taken together shorter than the second joint, the apical joint obliquely truncate; in the male the first joint of the flagellum is globose, the second scarcely longer than the first, the third scarcely one-half as long as the second, the fourth about equal in length to each of the following joints, the flagellum not clavate but longer than in the female. The anterior wings have two submarginal cells, the second receiving both recurrent nervures, the origin of the first recurrent nervure far beyond the origin of the cubital nervure; the stigma of good size; submarginal bullæ six, two on the first transverse nervure, one on the second, one on the first recurrent nervure, two on the second; basal lobe of the posterior wings extending beyond the middle of the submedial cell. Both sexes have the tarsal claws cleft and a distinct enclosure at the base of the posterior tibiæ. Posterior femora of the male swollen; posterior tibiæ in both sexes robust; basal joint of the posterior tarsi of the female quadrate, flattened, the upper angle not produced, the second joint attached at the lower angle; the posterior tibiæ and the basal joint of the posterior tarsi of the female clothed with a short, dense probescence upon which the pollen is collected in moist masses; basal joint of the posterior tarsi of the male armed with a regular comb of long teeth projecting from the inner margin of the lower face. Sixth segment of the abdomen of the female with a smooth enclosure on the disk. The seventh segment in the male with a triangular pyramidal projection on the disk, the apex of the projection obtuse, the anterior and longest side polished.

Art. XXXIV.—*Additional Remains of Jurassic Mammals;* by O. C. Marsh.

Beside the two mammals from the Jurassic beds of the Rocky Mountains already described by the writer,* two other specimens have recently been brought to light, from the same locality and horizon. Both are lower jaws, and apparently both pertain to the genus *Dryolestes*, and furnish important characters to distinguish it. In one of these specimens, the angle of the lower jaw is strongly inflected, thus indicating its marsupial nature. The other proves that the genus is quite distinct from *Didelphys*, as there were at least four premolars. The last lower premolar is compressed and trenchant, and not like the molars.

This specimen differs from the jaws of *Dryolestes priscus*, in being more slender, less curved, and less compressed. The symphysial surface is long, and only moderately roughened. The fourth lower premolar is in perfect preservation. It has two fangs, and the crown is very sharp, and much compressed. There is a slight tubercle on the front margin, and a low distinct heel on the posterior border.

The following measurements are from this specimen:

Space occupied by four lower premolars,	6·mm
Depth of jaw below first premolar,	2·5
Depth of jaw below fourth premolar,	3·
Width of jaw below fourth premolar,	2·
Height of crown of fourth lower premolar,	2·

The species represented by this specimen may be called *Dryolestes vorax*. The animal appears to have been rather smaller than *D. priscus*. The only known remains are in the Yale Museum.

Yale College, New Haven, August 8, 1879.

Postscript.—Since the above was in type, another lower jaw has been obtained from the same locality and horizon as those already noticed. This specimen is quite distinct from those described from this country, and in some respects resembles the genus *Triconodon* of Owen, from the Jurassic of England. The molar teeth have each three pointed cones, as in that genus. In the present specimen, however, there are four lower molar teeth, instead of three. The middle cone on each tooth is the largest, while in *Triconodon* they are nearly of the same size.† The last lower molar of the present specimen is only about half as large as those before it.

* This Journal, vol. xv, p. 459, 1878, and vol. xviii, p. 60, 1879.

† From *Phascolotherium*, with which it agrees more closely, the present genus may be distinguished by the greater number of teeth.

A striking feature in this jaw is the coronoid process, the anterior margin of which forms a right angle with the ramus, immediately behind the last molar. The angle of this jaw is much extended backward, but not perceptibly inflected. The condyle is low, and but slightly above the dental series.

The figure below gives the outline and general features of this specimen.

Right lower jaw of *Tinodon bellus*, Marsh. Twice natural size.

The principal dimensions of this specimen are as follows:

Space occupied by eight posterior teeth,.........	10· mm
Space occupied by four posterior molars, ...	6·
Distance from last molar to posterior end of jaw,	9·
Height of coronoid process above base of jaw,...	7·
Depth of jaw below last lower molar, ...	2·5
Depth of jaw below last premolar,..............	2·

This specimen indicates a new genus, which may be called *Tinodon*, and the species *Tinodon bellus*. The animal thus represented was apparently an insectivorous marsupial,* and in size somewhat smaller than those above noticed.

Yale College, August 16, 1879.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Spectrum of Ytterbium.*—Lecoq de Boisbaudran having received from Marignac a portion of his new earth ytterbia, has submitted it to spectroscopic examination. By using the chloride in solution in water, and the induction spark, he obtained a beautiful and distinctive spectrum formed for the most part of bands grouped between the solar lines D and F. Almost all of these bands are shaded from the left toward the right, the spectrum being so placed that the red end is at the left of the observer. The following are the bands observed, their positions being given in scale numbers: (1) Well marked band, slightly shaded from left to right, of intensity β; the left border nebulous at 103⅝, the apparent center at 104½. (2) Feeble band a little shaded from left to right, its apparent center at 107½. (3) Well marked and strongly shaded band, of intensity α; left border sharp at 109½,

* The elevated coronoid process, and the absence of inflection at the angle, suggest the possibility that this jaw may have belonged to a placental mammal. The latter character, with others of importance, indicate a distinct family, which may be called *Tinodontidæ*.

middle at 110¼, and the right and ill-defined edge at about ¼. (4) Well marked band, notably shaded from left to right, intensity δ_1; left edge slightly nebulous at 113$\frac{1}{10}$, the middle 114¼, and the ill-defined right edge at 115¾. (5) About 116¾, ulous beginning of a band with two maxima, of intensity δ_2, whole being well-marked, the principal brightness beginning about 118, the first and strongest maximum about 119, and the ldle of the second maximum at 121¼. Near 122⅛ is the very defined right edge of this band, which is united to the one next lowing by a slightly luminous background. (6) Band a little re feeble than that at 107⅛ and notably shaded; its left edge, newhat nebulous, being at 123¼, its middle about 124⅛, and its y nebulous right edge near 126. (7) Well marked band a le stronger than δ_1 at 114¼ and strongly shaded from left to ht, of intensity γ; left edge sharp at 126⅛, the middle being at $\frac{1}{20}$ and the right edge, ill-defined, at 129. (8) Band sensibly ded, of intensity ε; easily visible, but distinctly more feeble n δ_1 at 114¼; left nebulous edge at 130$\frac{1}{20}$, the middle at 131 l the right ill-defined border at 132¾. (9) Feeble band a little re nebulous on the right than the left edge, its apparent middle 134; united to the following band by a slightly luminous background. (10) Band very nebulous on both borders, about two isions broad, notably more marked than 134, and a little onger than 107⅛; the apparent middle and maximum of light t 135½. Bands 134 and 135½ together are easily visible. (11) ry weak nebulous band 1½ divisions broad, the middle being out 138. On the scale of the instrument, the solar lines read as lows: B 77¼, C 83$\frac{7}{10}$, D 100, E 121¼, F 141¾, G 180¼. Though at all necessary to establish ytterbium as a new element, the hor thinks that the existence of this specific emission spectrum interesting and may be of service as a means of recognizing s metal, especially in the absence of more precise knowledge of chemical properties.—*C. R.*, lxxxviii, 1342, June, 1879. G. F. B.

. *On Nitrification.*—WARINGTON has published a second per upon nitrification, giving the results of experiments made h the primary object of ascertaining the influence of light and nperature, and also of variations in the composition and contration of the solutions, upon the process, as well as the rate which the nitrification progresses and the relation of the nitric d produced to the ammonia consumed. The importance of the nclusions reached warrants us in giving them at some length. ey are as follows: 1. A solution of ammonium chloride, fully plied with plant-food, will not nitrify if germs be excluded. Such a solution containing calcium phosphate and potassium phate, but no organic salt or calcium carbonate, will not nitrify n when seeded. 3. Such a solution, supplied with sulphates l phosphates of potassium, calcium and magnesium, with cane ar, will not nitrify, even when seeded. 4. Such a solution taining potassium tartrate in addition to phosphates and sulates, may nitrify when seeded, but the nitrification takes place

very slowly, the salifiable base required, being furnished by the gradual decomposition of the tartrate. 5. Nitrification takes place speedily only when an excess of salifiable base, such as calcium carbonate, is present. 6. Nitrification may occur in solutions in which calcium salts are apparently absent. 7. A proportion of organic carbon (as tartrate) to nitrogen (present as NH_4Cl) equal to 3 : 10 by weight suffices for the purposes of nitrification, and probably even less would be sufficient. 8. Solutions containing as much as 640 milligrams NH_4Cl per liter can be completely nitrified, though the limit of concentration up to which nitrification is possible has not yet been ascertained. 9. Nitrification is not produced by the growth of mould which takes place in a solution containing tartrates. 10. It is not produced by growth of bacteria; at least bacteria may flourish in solutions of composition suitable for nitrification, without nitrification taking place. 11. Light certainly hinders nitrification; this is shown by every experiment save one. In twelve experiments out of thirteen, it is prevented or greatly delayed by exposure to light, or rather to alternate light and darkness. Evidence is yet wanting, however, that the nitrifying ferment is killed by light. In nitrification in the light, nitrites are abundant, even in weak solutions, and are very permanent. 12. Nitrification does not take place at the temperature of 40° C. Prolonged exposure to this degree of heat destroys apparently the ferment. 13. The addition of a small quantity of nitrifying solution to an ammoniacal solution of suitable composition is not immediately followed by perceptible action; a period of rest, often of considerable length, precedes the active work of the ferment. Whether this is due to the necessity of multiplying the germ to produce the effect or to the existence of the germ in a passive condition, is not yet settled. 14. Increase in the concentration of the ammoniacal solution lengthens the period of incubation. 15. Increase of temperature within certain limits greatly reduces the length of the period of incubation, it being shorter at 30° than at 20°. 16. The period of actual nitrification, which succeeds the period of incubation, increases with the concentration of the ammoniacal solution, and if the temperature be fixed, its length varies nearly as the degree of concentration. Strong solutions require rather less time in proportion to their strength than weak ones. 17. The period of actual nitrification diminishes greatly in length by rise in temperature; though it is not yet proved to be shorter at 30° than at 20°. 18. From 16 and 17, it follows that the average rate of oxidation increases up to a certain point with rise of temperature and is also somewhat increased with increasing concentration of the solution. 19. The rate of oxidation is not uniform throughout, the process of nitrification beginning slowly, then increasing in rapidity and after reaching a maximum, diminishes again toward the close. 20. The product of the nitrification is not uniform, sometimes nitrous and sometimes nitric acid being produced. A purely nitric fermentation has occurred only in the case of cold dilute solutions nitrified

in the dark. With strong solutions, or at elevated temperatures, or kept in the light, the nitrification is wholly or chiefly nitrous. Cold dilute solutions, in which nitrification is long checked by the absence of a salifiable base, also assume the nitrous fermentation on introducing such a base. 21. It does not appear that the production of nitrous acid is due to a deficiency of available oxygen; at least this is not a sufficient explanation for all the facts. It seems rather to depend on the condition of the ferment. 22. Nitrites produced during nitrification sometimes pass into nitrates with astonishing rapidity during the final stage of the process and before the ammonia has entirely disappeared. Under other circumstances they remain unchanged for a long time after the ammonia is all consumed. Light is apparently a condition which prevents nitrites from turning into nitrates. 23. The nitrifying ferment in certain conditions seems capable of producing nitrous acid only and is incapable, even in the dark, of converting nitrites into nitrates. 24. The whole of the ammonia is not finally obtained as nitric acid, the largest proportion so obtained being about 96 per cent; the mean of ten experiments being 93·7 per cent. In one exceptional experiment only 84·7 per cent was produced. 25. A solution of potassium nitrite remains, for a long time at least, without change, even in presence of tartrates, phosphates and calcium carbonate. But now, if a small quantity of a solution in which nitrites have been changed into nitrates, be added, the oxidation to nitrate is rapidly effected. This conversion takes place apparently only in the dark.—*J. Chem. Soc.*, xxxv, 429, July, 1879. G. F. B.

3. *On the Chemical Constitution of Alkali-metal Amalgams.*—BERTHELOT has investigated the question of the chemical composition of the amalgams which mercury forms with the alkali-metals. A series of these amalgams was prepared, some liquid, some solid, and treated with dilute hydrochloric acid, the heat evolved being measured. At the same time the quantity of the alkali-metal present was determined by analysis. The experiment was always made between 16° and 18°, the quantity of amalgam used being such that the variation of temperature in the calorimeter was between 1·5° and 4°. Beginning with a liquid amalgam containing 0·335 parts K to 100 parts Hg, or $Hg_{116}K_2$, the heat set free by the solution of one atom of K (39·1 grams) in dilute HCl, was 35·8 calories, and hence the heat evolved by one atom of K uniting with Hg was 26·2 calories. With 0·65 per cent K, or $Hg_{61}K_2$, still liquid though mixed with crystals, the heat in the former case is 31·3 and in the latter 30·2. With 1·34 per cent K, or $Hg_{29}K_2$, a pasty amalgam, the numbers are 27·8 and 33·7. With 1·85 K ($Hg_{20·8}K_2$), 27·25 and 34·2, the amalgam being solid. With 2 per cent K ($Hg_{19·2}K_2$), 26·7 and 34·8. With 3·40 ($Hg_{11}K_2$), 31·80 and 29·7. With about 8 per cent K, 41·2 and 20·3. With 8·2 K ($Hg_{4·4}K_2$), 40·7 and 20·8. With 11·85 K ($Hg_{2·9}K_2$), 46·2 and 15·3. Hence it appears that the heat of formation of these amalgams increases at first to a maximum and then diminishes again. This

maximum corresponds to a definite and crystallized amalgam analyzed by Crookewitt and by Kraut and Popp, containing 1·6 per cent K and having consequently the formula $Hg_{12}K$. Hg_{12} liquid $+ K = Hg_{12}K$ evolves 34·2 calories; or 27·5 calories if the Hg be solid; values comparable to those of combinations formed with powerful attractions, and lowering the heat of oxidation of K in its amalgams to $+48$ calories. If this amalgam be now dissolved in four times its weight of mercury, we have $26{\cdot}2 - 34{\cdot}2 = -8$ calories absorbed, a value of the same order as is given by the solution of saline hydrates. These results point out the existence of other solid and crystalline amalgams of potassium. Sodium acts similarly in amalgams, the maximum heat being 21·1 calories for one atom Na corresponding to 1·88 per cent Na ($Hg_{12}Na$) a solid, crystalline amalgam analyzed by Kraut and Popp. This gives for the heat of oxidation of Na when dissolved in Hg 56 calories. The attraction of K and Na for oxygen when free, is inverted in their amalgams. Hence the anomaly that sodium in an amalgam will displace the potassium in dissolved potassium hydrate.—*C. R.*, lxxxviii, 1335, June, 1879. G. F. B.

4. *On the Action of Dehydrating Substances upon Camphoric acid and its amides.*—In the hope of producing the nitrile of camphoric acid, which though an isomer of nicotine, is not, since the latter is a tertiary base, identical with it, BALLO has studied the action of dehydrating agents upon the camphoryl-amide of Laurent. According to the analogy with similar bodies, this amide under the influence of dehydration must split into the nitrile and water thus: $C_8H_{14}\left\{\begin{matrix}CONH_2\\CONH_2\end{matrix}\right. = (H_2O)_2 + C_8H_{14}\left\{\begin{matrix}CN\\CN\end{matrix}\right.$. So also camphoramic acid $C_8H_{14}\left\{\begin{matrix}CONH_2\\COONH_4\end{matrix}\right. = (H_2O)_3 + C_8H_{14}\left\{\begin{matrix}CN\\CN\end{matrix}\right.$; and ammonium camphorate $C_8H_{14}\left\{\begin{matrix}COONH_4\\COONH_4\end{matrix}\right. = (H_2O)_4 + C_8H_{14}\left\{\begin{matrix}CN\\CN\end{matrix}\right.$.

For the preparation of the amide, he at first passed ammonia gas into a solution of camphoric oxide in alcohol. But the alcohol was not entirely free from water and only ammonium camphorate resulted. The syrupy mass, heated with eight or ten times its weight of fused zinc chloride, gave an oily distillate consisting mainly of the hydrocarbon C_8H_{14}, which the author calls campholene and regards as identical with that obtained by Gille from campholic acid. This experiment shows that under this influence camphoric acid decomposes exactly as oxalic acid does: $C_8H_{14}\left\{\begin{matrix}COOH\\COOH\end{matrix}\right. = C_8H_{14} + CO_2 + CO + H_2O$. In a second experiment, the amide was attempted by acting on camphoryl chloride with ammonia. The product of the reaction was again a syrup, which, distilled with phosphoric oxide gave a yellow oil, boiling for the most part between 260° and 280° and having the composition of a polyterpene $C_{20}H_{32}$. From its origin, he called it camphoterpene. The third experiment was like the first, especial care being taken to free the alcohol completely from water. Ammo-

nium camphoramate was the result. Distilled alone, it gave camphorimide $C_8H_{14}\left\{\begin{matrix}CO\\CO\end{matrix}\right\}NH$. This body, distilled with zinc chloride yielded campholene and camphoterpene only, the resulting amide being saponified by the zinc chloride and the phosphoric acid. Ammonium camphoramate itself, distilled with phosphoric oxide directly, gave the desired nitrile mixed with campholene. Recrystallized from alcohol, it was obtained as a colorless crystalline body, odorless when pure and quite similar in appearance to the imide. Ballo closes his paper with some theoretical deductions, in which he formulates camphor as a tertiary alcohol $C\left\{\begin{matrix}(C_9H_{16})'''\\OH\end{matrix}\right.$, the carbinol of the trivalent radical C_9H_{16}; in which case borneol is the secondary alcohol $C\left\{\begin{matrix}(C_9H_{16})''\\H\\OH\end{matrix}\right.$ and menthol the primary alcohol $C\left\{\begin{matrix}(C_9H_{17})'\\H\\OH\end{matrix}\right.$.—*Liebig's Ann.*, cxcvii, 321, June, 1879. G. F. B.

5. *A new Synthesis of Methyl-violet.*—HASSENCAMP has described a new synthesis of methyl-violet. When a mixture of one part of pure benzene sulphochloride and two parts of dimethyl-aniline is warmed in a flask on the water bath, reaction takes place readily and a deep blue liquid results, becoming deeper and more violet continually until after some hours a thick mass is left having a strong metallic luster. The reaction goes on with great uniformity and no gas is evolved. The behavior of the new color to fibers first suggested that methyl-violet had been formed. On boiling out with water, the presence of phenyl sulph-hydrate is proven. Since the maximum yield is from one molecule of the sulphochloride and three of dimethyl-aniline, the reaction must take place as follows:

$$C_6H_5SO_2Cl+(C_6H_5N(CH_3)_2)_3=\left.\begin{matrix}(CH_3)_2NC_6H_4\\(CH_3)_2NC_6H_4\end{matrix}\right\}C\left\{\begin{matrix}C_6H_4\\|\\NCH_3\end{matrix}\right.+HCl+$$

$(H_2O)_2+C_6H_5SH$.—*Ber. Berl. Chem. Ges.*, xii, 1275, July, 1879. G. F. B.

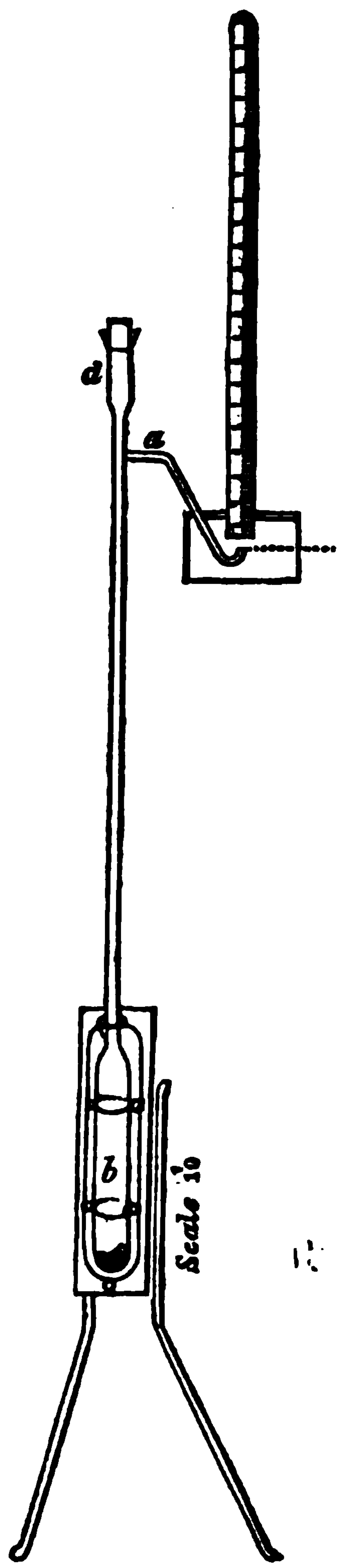
6. *On the Alkaloids of Japanese Aconite Roots.*—WRIGHT, in connection with LUFF and subsequently with MENKE, has examined the alkaloids contained in some aconite roots recently imported into England from Japan. The conclusions of the paper are: (1) Aconite roots from Japan are tolerably uniform in character and considerably richer in active crystallized alkaloids as well as non-crystalline bases than *A. napellus.* (2) The active crystalline alkaloid is, as Paul and Kingzett suppose, different from both aconitine and pseudaconitine, though closely allied to both, especially the former. (3) Only one crystallized alkaloid could be isolated from each of three different batches of roots. This has the formula $C_{66}H_{81}N_2O_{21}$. (4) This alkaloid, to which

the name japaconitine is assigned, breaks up upon saponification into benzoic acid and a new base japaconine, $C_{26}H_{41}NO_{10}$. On treatment with benzoic oxide, it forms derivatives containing four benzoyl groups for every C_{33} originally present; differing from aconitine, which gives only a di-benzoyl derivative. Japaconine gives the same derivative on benzoylation. These alkaloids closely resemble aconitine and aconine and are distinguished only by analysis or by their benzoyl derivatives. Japaconitine forms readily crystallizable salts especially with nitric, hydrochloric and hydrobromic acids, the latter salt containing 2½ H_2O for every C_{33}, like aconitine. (6) In isolating japaconitine, plain alcohol, instead of alcohol acidified with tartaric acid must be used. All the alkaloids are easily extracted thus. (7) The relation of japaconitine to its derivatives and to aconitine is conveniently expressed by regarding it as formed by the sesquihydration of an alkaloid $C_{33}H_{47}NO_{12}$ not yet isolated.—*J. Chem. Soc.*, xxxv, 387, July, 1879.
G. F. B.

7. *Determination of Vapor Densities.*—The method of determining the density of vapors invented by Victor and Carl Meyer has already been noticed in this Journal, and the chief results which they have obtained by means of it have been stated. But this method demands more than a passing notice. It is so simple in its theory and manipulation, so universal in its application, and it avoids in such a remarkable way the main difficulties and sources of inaccuracy, which are inherent in all the methods hitherto employed for the same purpose, that it promises to become one of the most important aids in the investigation of chemical science. The theory of the method may be stated thus.

If a known amount of some volatile substance is suddenly dropped into an appropriate vessel heated to a constant temperature, which is sufficiently high to convert the material to an aeriform condition, it is obvious that the substance in volatilizing will expel from the vessel a quantity of air, which must be the exact equivalent of the volume of vapor formed—that is, an amount of air which at the unknown temperature and pressure in the vessel would just fill the space of the vapor. Hence then the specific gravity of the vapor is the known weight of the material used divided by the weight of the air expelled. The problem is thus reduced to finding the weight of the air expelled, and is wholly independent of the temperature or volume of the vessel, both of which may remain unknown quantities. All the uncertainties, therefore, connected with the measurements of high temperatures, or of the volume of the vessel under such conditions, are avoided. We have only to collect the air over a common water pneumatic trough and measure its volume, at the ordinary temperature and pressure of the air in the laboratory, and from these data we can easily calculate the weight required; or, if the material under examination is liable to oxidation, the vessel may be previously filled with nitrogen or some other inert gas, since the volume of such gas will be the same as the volume of the air under the same circumstances.

The only apparatus required in most cases is represented in the accompanying figure, which is drawn to scale. The bulb *b* has a capacity of about 100 $\overline{c.m.}^3$ and is about 20 c.m. long, and the glass tube to which it is attached is about 60 c.m. long and 6 mm. wide. The upper end of this tube is closed by a rubber stopper *d*, while to its side is united the very narrow delivery tube *a*, which conducts the expelled air to a pneumatic trough. By means of a wire guard the bulb is prevented from touching the sides of the iron bath in which it is heated, and a small amount of asbestos at the bottom of the bulb serves to break the fall of the small weighing tube, holding the weighed substance, which is dropped in at *d*. The iron bath is made of a short piece of two-inch gas pipe closed by welding at the bottom, and supported on a tripod of such height that, while the tripod stands on the floor, the pneumatic trough may stand on a table of medium height. In the bath may be used paraffine or a molten metal as circumstances require, and its temperature is maintained by gas burners, more or less powerful according to the temperature to be obtained. For comparatively low temperatures the most convenient bath is the vapor of some high boiling liquid, whose ebullition is so regulated that the vapor condenses before reaching the open mouth of the long necked boiling flask in which the bulb is held. In a bath of melted lead a low red heat is easily obtained, and it has been found that tubes of Bohemian glass will readily sustain this temperature without collapsing, for, although the glass may take a new set under the circumstances, the resulting change of volume is of no importance in this process. In their later experiments, the Brothers Meyer have used a porcelain vessel, heated in the muffle of a gas furnace to a temperature above the melting point of cast-iron.



After the bath has been heated to the degree required, and its temperature has become constant (a condition which is indicated by the fact that bubbles of gas cease to escape from the open mouth of the tube, while at the same time there is no tendency in the water to recede) the necessary observations are made in a very simple way. The stopper at *d* is removed, the small tube containing the weighed substance is dropped in, and the stopper instantly replaced. The few bubbles of air displaced by the stopper are of

course neglected; but the air, which soon begins to stream over in consequence of volatilization of the material introduced, is collected over water in an ordinary graduated tube. The experiment is soon finished, and the stopper *d* must then be removed, to prevent any recession of the water in the trough.

It remains only to measure the volume of the air in the graduated tube with the usual precautions. For this purpose the tube with its contents is transferred to a tall cylindrical glass vessel of water, and held by a clamp in a vertical position, so that the water is at the same level within and without the tube, and, as soon as an equilibrium of temperature is attained, we observe the volume of the air, the temperature of the air (necessarily the same as that of the water confining it) and the height of a neighboring barometer. We have now V, H and *t*, from which we can calculate the corresponding weight. But in making this calculation we must remember that the air when measured is saturated with moisture, and therefore, that in order to find the true tension of the confined air, we must subtract from the *reduced height* of the barometer the maximum tension of the vapor of water at the temperature *t*. Representing by *h* this tension (which will be found in Regnault's tables), we have for the weight of the air displaced by the vapor

$$W' = 0{\cdot}001293 \frac{H-h}{76} \cdot \frac{273}{273+t} V;$$

and if W represents the weight of the substance used

$$\text{Sp. Gr.} = \frac{W}{W'}.$$

For convenience of logarithmic calculation these formulæ are easily combined into the following form:

$$\log(\text{Sp. Gr.}) = 2{\cdot}3330 + \text{ar. co.} \log(H-h) + \log(273+t) + \text{ar. co.} \log V + \log W.$$

In these determinations it is important that the amount of substance taken should never more than one-half fill the vessel *b* with vapor, lest, in the process, some of the vapor should be driven out with the air. The least loss of material caused in this way would evidently be fatal to the accuracy of the method; but, short of such a result, no admixture of the vapor with the air in the vessel can affect the process; since, according to the well-known laws of Dalton, *the elastic force of a mixture of gas and vapor is equal to the sum of the tensions which each would have separately.* In the case of a heavy vapor, no considerable mixing with the air during the short time of the experiment was to be feared, but, when the vapor was lighter than air, such a rapid admixture as would lead to large loss—even when the volume of the vapor was small as compared with that of the vessel—might reasonably be expected. Hence it was with surprise that the method was found to be applicable to light, vapors

; following example shows, selected for this reason to illus- the manner in which the calculations are best made.

ample.—Determination of the specific gravity of the vapor ter: The vessel was heated to a constant temperature in the s of xylol and a tube containing 0·0102 grams of water ›ed in as described. The air expelled measured 14·6 c.m. at and the reduced height of the barometer in the room was c.m. By the tables the maximum tension of the vapor of · at 16°·1 is 1·36 c.m. Hence

Constant log	2·3330
$H-h$=70·97 or. co. log	8·1490
$273+t$=289·1 log	2·4611
V=14·6 ar. co. log	8·3356
W=0·0102 log	7·0086
Sp. gr. 0·613	9·7873

Theory H_2O 0·623

o other independent determinations of the same value gave ınd 0·64 respectively.

account of the great ease with which vapor densities can be mined by this process, we have reason to hope that it will to greatly multiply the fundamental data on which our ledge of molecular weights is based. Already some remark- results of this kind have been obtained. Thus the vapor ties of arsenious and antimonious oxide at the temperature ›lten cast iron have been found to be 13·8 and 19·8 respec- ' (the mean in each case of two determinations), and these spond to the symbols As_4O_6 and Sb_4O_6 instead of the received ols As_2O_3 and Sb_2O_3. On the other hand cuprous chloride at ame high temperature gave a vapor density of 6·93, corres- .ng to Cu_2Cl_2, thus confirming the received opinion in regard constitution, which was previously based chiefly on theoret- onsiderations connected with the atomicity of its elements.

the Berichte der Deutsch. Chem. Gessell. of July 28th, re- 1 since the above was in type, we have an account of a still remarkable result which the Brothers Meyer have obtained their method of determining vapor densities. Having in the ›lace established the fact that mercury and oxygen (by exper-), and nitrogen (by inference), retain their normal vapor or gas ty and therefore their normal molecular structure even at the st temperature of a gas furnace, about 1567° C., they next imented on chlorine, by dropping a weighed amount of $PtCl_2$ the heated porcelain vessel above described; and it appears these experiments that at temperatures above 800° chlorine ndergoes disassociation. Thus at about 620° the density was 2·42, 2·46.

Theory for Cl_2 2.45

At about	808° the density found was		2·21	2·19
"	1028°	" "	1·85	1·89
"	1242°	" "	1·65	1·66
"	1392°	" "	1·66	1·69
"	1567°	" "	1·60	1·62

Theory for ⅔ Cl_2 1·63

Hence between 1242° and 1567° the density of chlorine gas is constant at two-thirds of its normal value, and its molecular weight which is normally 71 becomes at temperatures above 1200°, equal to 47·3. In the present paper the Brothers Meyer offer no definite explanation of this most remarkable result, but they refer to the old theory which regarded chlorine as an oxide as furnishing a possible explanation of the anomaly and propose to attempt to separate by diffusion at 1567° the disassociated elements of chlorine if such exist. J. P. C., JR.

8. *Compressibility of gases at high pressures.*—Amagat continues his work upon this subject at St. Etienne in a shaft 380 meters deep. He proposes to study a series of gases and gives, as a preliminary result, his observations upon nitrogen, taking this gas for a basis on account of the facility with which it can be prepared in a comparatively pure state. The results are given in the following table. P represents the pressure in meters of quicksilver, P′ the atmospheric pressure, v the original volume, Pv the product of the pressure and the volume.

P	P′	Pv	$\frac{Pv}{P.v.}$
96·698	127·223	51594	----
128·296	168·684	52860	0·9760
158·563	208·622	54214	0·9516
190·855	251·127	55850	0·9238
221·103	290·924	57796	0·8927
252·353	332·039	59921	0·8613
283·710	373·302	62708	0·8297
327·388	430·773	65428	0·7885

The temperature was maintained nearly constant from 22·00 to 22·03°. At 430 atmospheres it was found that the gas volume was one-fourth smaller than it should be according to Marriotte's law.—*C. R.*, lxxxviii, 1879, p. 336; *Beiblatter Annalen der Physik*, No. 6, 1879, p. 414. J. T.

9. *Elements of Modern Chemistry;* by ADOLPHE WURTZ, Professor of Chemistry of the Faculty of Medicine of Paris, etc. Translated, with the Author's approval, by Wm. H. Green, M.D. 687 pp. 12mo, with 132 illustrations. Philadelphia, 1879. (Lippincott & Co.).—In a preface to this American edition of Professor Wurtz's Chemistry, the author states that his friend and former pupil, Dr. Green, presents in this translation "a faithful, or even improved, representation of the original work." The hand of a master is seen in this book, which is simple, direct, and symmetrical in its discussion of elementary facts and principles. The subject of Chemical Philosophy is naturally divided under two heads; so much as is essential to the study of the metalloids is compressed into less than fifty pages, at the commencement of the volume, while the theory of Atomicity, the Constitution of Salts and Classification of Metals are treated in about the same space before the metals. The general ideas upon the Constitution of Organic Compounds are compressed into about thirty pages preceding that subject. Many teachers and students will gladly adopt this book as a manual. Its order is logical and the main

:ts of discovery are clearly stated, and, as far as possible, in his-
:ical order, with a severe exclusion of extraneous matters. Its
efulness would be increased by a synoptical table of contents
d a fuller index of proper names and subjects: e. g., one looks in
.in for such important words as molecule, atom, Ampère, Avo-
ado, volume, gas, and many other equally essential terms. A
·ench work has rarely a good index; but an English translation
ed not repeat this fault. In these days, when gas has com-
etely replaced the old-time charcoal furnaces as a source of heat
the laboratory, it looks strange to see these historic things re-
oduced from old cuts in the newest French book. B. S.

II. Geology and Mineralogy.

1. *Discovery of specimens of Maclurea magna, of the Chazy, the Barnegat limestone, near Newburg, New York;* by R. P. 'HITFIELD. (From a letter to J. D. Dana, dated American Mu- um of Natural History, Central Park, New York, July 30, 1879.) ·Being on business at Newburg, New York, on July 19th last, I opped for a few minutes, in passing a quarry of the Barnegat nestone, situated near the northwest base of Snake Hill on the Little Pond Road" one and three quarter miles southwest of New- ırg Ferry, where I obtained from the thin shaly layers of the nestone, remains of three specimens of *Maclurea magna* Les., one ' which is sufficiently well preserved to be unmistakable.

This information may aid somewhat in determining the age of ıe Taconic schists which you have been so ably discussing, and so serve to confirm the statement made by you on page 382 of ıe May number of this Journal.

2. *On a recent Silent discharge of Kilauea;* by Dr. TITUS OAN. (From a letter to J. D. Dana, dated Honolulu, Hawaii, ıne 20, 1879.)—You may have heard, ere this, that Kilauea has gain disgorged a fiery flood, and retired within her subterranean ıambers. A little over ten years had elapsed, during which time ıe repairs of the eruption of 1868 were going on, until the nptied "South Lake" was replenished, "heaped up and running ver;" when, without premonition, an unknown subterranean pas- ıge was opened and the vast fiery basin was emptied, as in 1868.* ut this disgorgement was hidden and peculiar. The lake of ısion, which had been raised, by its self-made surrounding wall, early to the height of the outer rim of the crater, quietly sub- ded several hundred feet, ceased its boiling and nearly extin- uished its fires, leaving nothing but a vast smoking cauldron.

You may remember that after the grand eruption of 1868, I suc- eded in scrambling down into the bottom of this evacuated pit, bout 400 feet deep, and measuring across its bottom, a distance f one mile minus about 100 feet. This awful cauldron had only

* Mr. Coan does not mention the precise time of this eruption; but, from some atements in the Sandwich Island papers, it probably took place in April last. ıe "South Lake" referred to is in the bottom of Kilauea; and, though large, is nall compared with the area of the bottom of the pit, the longest diameter of hich is 3½ miles. J. D. D.

a few days before been filled to overflowing with boiling lava, raging, rolling in fiery waves from side to side of the glowing pit, dashing against its heated walls and throwing up its sheets and spouts of liquid fire 20, 40 and 50 feet into the air, while the surrounding deposits of solidified scoria formed a smoking mountain. Out of the northern and northwest sides of this accumulated mass of volcanic products streams of liquid lava burst from time to time, flowing down into the central region of the crater, and thus raising it, foot by foot, for months and years. Added to these subaerial outflows, there were oft-repeated, upward or vertical gushings of lava through seams and crevices; and thus, by these twofold actions, the great central depression, caused by the subsidence of a very large area of this part of the crater, was gradu ally filled up.

One feature of this last eruption of Kilauea is the fact that the great molten lake was drawn off subterraneously, giving no warning of its movements, and leaving no visible indication of its pathway, or of the place of its final deposit. Other eruptions have blazed their way upon the surface to the sea, or while on their subterranean way have rent the superincumbent beds, throwing out jets of steam or of sulphurous gases, with here and there small patches or broad areas of lava. But as yet no surface marks of this kind reveal the silent, solemn course of this burning river. One theory is that it flowed deep in subterranean fissures, and finally disembogued far out at sea. Our ocean was much disturbed during these days, and we had what might be called a tidal wave of moderate magnitude. For some time after this eruption, Kilauea lay with scarcely any visible fire, and only here and there puffs of white steam and jets of escaping gases. All visitors were for several weeks greatly disappointed, and some were inclined to think that the vivid descriptions of former visitors were fabulous; but later advices report the old goddess as arousing from her slumbers, stirring up the coals, lighting her lamps and sending out fiery glances from her red eye-balls. So the old process of replenishment has begun and after another decade another disgorgement may take place.

Mokuaweoweo, the summit crater, has been quiet for a long time. Moderate earthquakes occasionally admonish us that nothing earthly is stable; our aerial thunders have never been more sublime than during March, April and May.

3. *The recent Eruption of Etna.*—In regard to this eruption we have before us the report of Professor O. Silvestri of the University of Catania to the Italian Ministry, and also the report of G. H. Owen, U. S. Consul at Messina, to the Department of State. The former is a quarto pamphlet of nineteen pages, with an excellent topographical map of the region to the distance of about twenty kilometers from the summit in all directions. Upon this is charted not only the course and extent of the recent outflow of lava but those of previous eruptions also.

Silvestri regards the recent eruption as a sequel to that of August 29, 1874, when a rift opened upon the northeastern side of the

mountain, along which a number of eruptive mouths were formed and from which lava was discharged. At that time however the activity continued for only a few hours, although the rift remained open for some days. In his notice of that eruption (Bulletino del Vulcanismo Anno I.) Silvestri predicted that at the next eruption this rift would prove the weakest point and would be the scene of the outbreak. This is exactly what has happened. This fissure of 1874 has become extended, reaching across the main crater in a north-northeast and south-southwest direction, to a length of ten kilometers. And from its extremities the lava has poured forth, beginning on the evening of May 26th. On the southwest it took the direction of the old lava flow toward the town of Adernó, but its course was arrested after flowing about two kilometers. From the northeastern extremity of the rift the flow extended in the direction of Mojo, continuing to advance until about June 6, when it had reached a distance of eleven kilometers from its source, and its front had stopped but a short distance from the river Alcantara. Further details of Professor Silvestri's report may be found by English readers in Nature, June 26, 1879.

A paper presented to the Paris Academy of Sciences by M. Fonquè, says that "on the north-north-east side there are ten distinct craters, two of which are enormous (200^m diameter, and 80^m depth)."

The report of U. S. Consul Owen to the State Department is dated Messina, June 20, and in it he says: "The eruption was preceded by a slight shock of earthquake that was felt throughout the island and at Reggio on the continent. Two new craters were opened, one near the summit on the south-southwest side of the mountain and the other on the north-northeast lower down the slope. The former ceased to erupt after a day and half, while the latter continued its eruption till the 11th inst. The discharges of lava, especially on the side last mentioned, were attended by great shaking and trembling of the soil and loud detonations that could be heard at a distance of twenty miles. At the same time the crater began to emit great clouds of dense black smoke, ashes and cinders, that fell on the surrounding country in a shower, and were carried by the strong sirocco blowing at the time even as far north as the province of Naples. In Messina the pavements and balconies were covered with this black dust, and during its fall, which was of ten hours duration, it was disagreeable to go out of doors with the eyes unprotected. The lava, contrary to general opinion, was not a stream of liquid fire, but rather resembled a moving mass of stones in a state of incandescence, for as each successive discharge would expel the matter in a half melted condition, it would accumulate at the mouth of the crater, where cooling, it would remain, until pressed forward by the discharges of new lava. The flow, if so it can be called, was very gradual. The stream of lava toward the northeast was 700 meters in width and the distance traversed about eleven kilometers.

"The damages caused by the eruption have been estimated at 1,000,000 of liras. The property damaged consisted of vineyards

and nut groves. Fortunately no lives were lost or villages destroyed.

"On the 15th inst. strong shocks of earthquake were felt at Riposto. The ground opened and many houses were shaken down. On this occasion eight persons were killed and many wounded. It is believed that the earthquakes were caused by the undermining of the soil owing to the recent eruptions."

C. G. R.

4. *Former extension northward of the South American Continent.*—The following paragraphs close a paper by A. AGASSIZ, entitled, Dredging Operations of the U. S. Coast Survey Schooner "Blake," from December, 1878, to March 10, 1879, in a Letter from A. Agassiz to C. P. Patterson, Sup't Coast Survey. (Bull. Mus. Comp. Zool., Cambridge, Mass., vol. v, No. 14, June, 1879.) The paper is illustrated by a map of the Carribean Sea, supplied by the Superintendent of the Coast Survey, which is highly instructive.

One of the most interesting results reached by this year's cruise is the light thrown upon the former extension of the South American Continent, by the soundings taken while dredging, and those subsequently made in the passages between the islands by Commander Bartlett. These, together with the soundings already known, enable us to trace the outline of the old continent with tolerable accuracy, and thus obtain some intelligible, and at the same time trustworthy, explanation of the peculiar geographical distribution of the fauna and flora of the West India Islands. As is well known, Cuba, the Bahamas, Hayti and Porto Rico, instead of showing, as we might naturally assume from their present proximity to Florida, a decided affinity in their fauna and flora with that of the Southern United States, show, on the contrary, unmistakable association with that of Mexico, Honduras and Central America; the Caribbean Islands show in part the same relationship, though the affinity to the Venezuelan and Brazilian fauna and flora is much more marked.

In attempting to reconstruct, from the soundings, the state of things existing in a former period, we are at once struck by the fact that the Virgin Islands are the outcropping of an extensive bank. The greatest depth between these islands is less than 40 fathoms, this same depth being found on the bank to the east of Porto Rico, the 100-fathom line forming, in fact, the outline of a large island, which would include the whole of the Virgin Islands, the whole of Porto Rico, and extend some way into the Mona Passage. The 100-fathom line similarly forms a large plateau, uniting Anguilla, St. Martin and St. Bartholomew. It also unites Barbuda and Antigua, forms the Saba Bank, unites St. Eustatius, St. Christopher, Nevis and Redonda. It forms an elongated plateau, extending from Bequia to the southwest of Grenada, and runs more or less parallel to the South American coast from the Margarita Islands, leaving a comparatively narrow channel between it and the 100-fathom line south of Grenada, so as to enclose Trinidad and Tobago within its limits, and runs off to the

southeast in a direction also about parallel to the shore line. At the western end of the Caribbean Sea, the 100-fathom line forms a gigantic bank off the Mosquito coast, extending over one-third the distance from the mainland to the island of Jamaica. The Rosalind and Pedro Banks, formed by the same line, and a few other smaller banks, denote the position of more or less important islands which must have once existed between the Mosquito coast and Jamaica. On examining the 500-fathom line, we thus find that Jamaica is only the northern spit of a gigantic promontory, which once extended toward Hayti from the mainland, reaching from Costa Rica to the northern part of the Mosquito coast, and leaving but a comparatively narrow passage between it and the 500-fathom line encircling Hayti, Porto Rico and the Virgin Islands, in one gigantic island. The passage between Cuba and Jamaica has a depth of 3,000 fathoms, and that between Hayti and Cuba is not less than 873 fathoms, the latter being probably an arm of the Atlantic. The 500-fathom line connects, as a gigantic island, the banks uniting Anguilla to St. Bartholomew, Saba Bank, the one connecting St. Eustatius to Nevis, Barbuda to Antigua, and from thence extends south so as to include Guadeloupe, Marie-Galante and Dominica. This 500-fathom line thus forms one gigantic island of the northern islands, extending from Saba Bank to Santa Cruz, and leaving but a narrow channel between it and the eastern end of the 500-fathom line running round Santa Cruz. As Santa Cruz is separated from St. Thomas by a channel of forty miles, with a maximum depth of over 2,400 fathoms, this plainly shows its connection with the northern islands of the Caribbean group, rather than with St. Thomas, as is also well shown by the geographical relations of its Mollusca. The 500-fathom line again unites, in one gigantic spit extending northerly from the mouth of the Orinoco, all the islands to the south of Martinique, leaving Barbadoes to the east, and a narrow passage between Martinique and the islands of Dominica and St. Lucia. At the time of this connection, therefore, the Caribbean Sea connected with the Atlantic only by a narrow passage of a few miles in width between St. Lucia and Martinique, and one somewhat wider and slightly deeper between Martinique and Dominica, another between Sombrero and the Virgin Islands, and a comparatively narrow passage between Jamaica and Hayti. The Caribbean Sea, therefore, must have been a gulf of the Pacific, or have connected with it through wide passages, of which we find the traces in the Tertiary and Cretaceous deposits of the Isthmus of Darien, of Panama and of Nicaragua. Central America and northern South America at that time must have been a series of large islands with passages between them from the Pacific into the Caribbean. It is further interesting to speculate what must have become of the great equatorial current, or rather of the current produced by the northeast trades. The water banking up against the two large islands, then forming the Caribbean Islands, must, of course, have been deflected north, have swept round the northern shores of the Virgin Islands, Porto Rico and Hayti, and

poured into the western basin of the Caribbean Sea, through the passage between Hayti and Cuba. This water being forced into a sort of funnel, by the 500-fathom line forming the southern line of the Great Bahama Island, which connected nearly the whole of the Bahamas with Cuba and formed a barrier to the western flow of the equatorial current, this must, therefore, for the greater part, have been deflected north, and either swept in a northeasterly direction, as the Gulf Stream now does, or round the north end of the Bahamas, across Florida, which did not then exist, across the Gulf of Mexico, and into the Pacific over the Isthmus of Tehuantepec.

The soundings made by Commander Bartlett, after I left the "Blake," to determine the ridges uniting the various islands between Sombrero and Trinidad, show plainly that the cold water of the Caribbean can only come in through the passage between Sombrero and the Virgin Islands, which is about 1,100 fathoms, with a bottom temperature of 38°, while the 500-fathom line, as I have said, forms a gigantic island of all the islands to the south of Sombrero, including Dominica, with a narrow passage of 1,000 fathoms between it and Martinique; the 500-fathom line again uniting into one large spit, as a part of South America, all the islands to the south of it. Thus the bulk of the water forced into the Caribbean Sea has a comparatively high temperature,—an average, probably, of the temperature of the 300-fathom line. The cold water of the Atlantic is, however, again forced into the western basin of the Caribbean through the Windward Passage, and all this through the Yucatan Channel, between Cape San Antonio and the Yucatan Bank. It is, therefore, incredible that with this huge mass of water pouring into the Gulf of Mexico, there should be anything like a cold current forcing its way uphill into the Straits of Florida, as has been asserted on theoretical grounds. The channel at Gun Key can only discharge the surplus by having a great velocity.

Mr. Garman, who as usual accompanied me, remained in the West Indies, after we left the "Blake" at Barbadoes, for the purpose of making collections of Reptiles and Fishes, with a view of throwing additional light on the former connections of the islands, as I have here attempted to trace it. One of the most interesting of the Reptiles we collected is a gigantic land tortoise, found at Porto Rico, differing only in size from the land turtle still found on Trinidad and adjoining parts of South America. It is closely allied to the gigantic turtles of the Gallopagos, and to the fossil land turtles, of which fragments have been described by the late Professor Wyman. These were collected by Mr. A. Julien at Sombrero, in the phosphate beds of the island.

5. *Footprint in the Mesozoic rocks of New Jersey.*—Mr. J. C. Russell has obtained at Boonton, New Jersey, a fine three-toed or Ornithoid track, in the Mesozoic rock of the region. It measures 6·2 inches in length, and 5·5 in width.

6. *Footprints from the Anthracite Coal Measures, of the Mahanoy Coal Field, at the Ellangowan Colliery.*—A slab, having upon

it ripple-marks and seven footprints, has been obtained at this locality by Mr. W. Lorenz The tracks, according to Dr. Leidy, have a breadth of about an inch, widely divergent toes, and the four on the right occupy a line of six inches and are about an inch and a half apart from those on the left; they appear to be single, that is, not made by fore and hind feet together. Mr. Lorenz suggests for them the name *Anthracopus Ellangowensis.*—*Proc. Acad. N. Sci. Philad.*, 1879, 164.

7. *The Auriferous Gravels of the Sierra Nevada and California;* by J. D. Whitney (continued from page 147.)—The following are the more important facts with regard to the fossils of the auriferous gravels. The *plants* were submitted to Professor Lesquereux; and he has reported the absence of Coniferous remains, that the species of deciduous trees, seventeen of which are from the Table Mountain deposit, are different from those now existing in the region; and that the evidence favors the view that the beds are Pliocene, but related by some forms to the Miocene.

The *mammalian remains* have been determined by Dr. Leidy, and his results are published partly in vol. I of the California Reports, and the remainder in his works on the Extinct Mammalian Fauna of Dakota and Nebraska, 1869, and Contributions to the Extinct Vertebrate Fauna of the Western Territories, 1873. The species reported from the gravels underneath basalt, come from Douglass Flat, Chili Gulch, and the Tuolumne Table Mountain. At the first two of these places were found remains of *Rhinoceros hesperius* Leidy; at Douglass Flat, a tooth of *Elotherium superbum* L., "perhaps the same as *E. ingens* of the Mauvaises Terres of White River;" *Mastodon Americanus*, forty-eight feet beneath the surface at Douglass Flat and also at the Tuolumne Table Mountain; and a portion of a humerus of a small species of *Equus*, from a depth of 210 feet, at the Table Mountain. Besides these, the gravels elsewhere have afforded, at Murphy's Diggings, west of Douglass Flat, a tibia of *Canis latrans;* in Merced County, near the line of Mariposa, in volcanic ash, remains of an extinct lama, *Auchenia Californica* L., besides a metacarpal "probably of a deer, some bones of a small horse, perhaps a Hippárion; from Alameda County, *Auchenia hesterna* L.;" from the gravels near Sonora, two teeth of the living American Tapir; at different points, *Mastodon Americanus*, "up to an elevation little if at all exceeding 3,000 feet," with also *M. obscurus* L.; at several localities also, *Elephas Americanus*, one nearly perfect skeleton near the Fresno River; *Equus caballus*, *E. excelsus* L., *E. pacificus* L.

Stone implements (including tools, pestles, mortars, platters, spear and arrow heads, etc.), are reported, from the gravels at the following localities, and if some are doubtful, the number of places is so large that the fact of occurrence in the gravels cannot be reasonably questioned. In Mariposa County, at Horse Shoe Bend, on the Merced River, at Hornitos and five miles northeast, and near Princeton; in Merced County, near Snelling; in Stanislaus County, at Dry Creek; in Tuolumne County, at Table Mountain,

Kincaid Flat, Wood's Creek, Mormon Creek; in Amador County, near Jackson; in El Dorado County, at Shingle Springs, Diamond Springs near Placerville, Spanish Flat, Kelsey's Diggings, Dry Creek, Coloma, Georgetown, Brownsville; in Placer County, near Gold Hill, Forest Hill, Byrd's Valley, Missouri Tunnel; in Nevada County, at Grass Valley, Myer's Ravine, Brush Creek; in Butte County, at Cherokee; also in Siskiyou and Trinity Counties, localities not mentioned.

Human bones are reported from Tuolumne and Calaveras Counties. (1.) Under Table Mountain, Tuolumne County, a human jaw, obtained by Dr. Snell; same locality, in the Sonora tunnel, at a depth of 180 feet, a portion of a skull given to C. F. Winslow in 1857, by P. K. Hubbs, of Vallejo, California, the finder, and by the former noticed in the Proceedings of the Boston Society of Natural History, for October 7, 1857, the same locality affording also a Mastodon's tooth and a "large stone bead" of white marble. Mr. Winslow also says that Capt. D. B. Akey related to him a discovery of a complete human skeleton from a tunnel under Table Mountain, but stated that he did not remember the tunnel, and the fact has not been verified.

(2.) In Calaveras County, in February, 1866, in the claim of Messrs. Mattison & Co., on Bald Mountain, near Altaville and Angel's, beneath the lava, from a depth of 130 feet. This is the skull which came into Professor Whitney's hands through Dr. Jones, who received it from Mr. Mattison, and which has been described by Dr. Jeffries Wyman. The material in which it had been embedded was mixed tufa and gravel, and attached to it was a specimen of *Helix mormonum*, a species now living in Nevada. According to Mr. Mattison, the succession of beds passed through from above to that containing the skull, was black lava, 40 feet; next below, gravel 3, light lava 30, gravel 5, light lava 15, gravel 25, dark brown lava 9, gravel (that containing the skull) 5. This bed rested on red lava 4 feet and red gravel 17 feet. Professor Whitney brings forward the testimony of Mr. Scribner and also of Dr. Jones; and says, "We have the independent testimony of three witnesses, two of whom were previously known to the writer as men of intelligence and veracity, while in regard to the third there is no reason for doubting his truthfulness. Each one of these gentlemen testifies to some points in the chain of circumstantial evidence going to prove the genuineness of the find. No motive for deception on the part of Mr. Mattison can be discovered, while the appearance of the skull itself bears strong, though silent, testimony to the correctness of the story."

Dr. Wyman's report, as is now well known, stated that the "skull presents no signs of having belonged to an inferior race. In its breadth it agrees with the other crania from California, except those of the Diggers, but surpasses them in the other particulars in which comparisons have been made. This is especially apparent in the greater prominence of the forehead and the capac-

s chamber. In so far as it differs in dimensions from the ınia from California, it approaches the Esquimaux." The g are the comparisons above referred to by Dr. Wyman, ɜurements being in millimeters:

	Breadth of Cranium.	Breadth of Frontal.*	Frontal Arch.	Length of Frontal.	Height of Cranium.	Zygomatic Diameter.
ıaux	134·5	94	296·5	126·6	135	137·6
laska	133·5	92·8	285·5	121·8	129·5	132
fferent parts of Cal.	150·5	93·5	260	117	120·8	134
Indians	136·6	88·3	280	119	120·3	141·5
ssil skull	150	101	300	128	134†	145

ısor Whitney regards the gravels as Pre-Glacial, and Plio- the basis of the evidence from the fossils found in them. ;in of the gravels remains to be discussed by him in the ›art of the volume, which, according to a prefatory note, ›ublished in a few months.

ne Cave in Moravia.—A large number of mammalian ' the diluvian period have lately been obtained from the ·e of Vypustek, Moravia (Professor K. Th. Liebe, Proceed. cad. Vienna, May 23, 1879), and sent to the Imperial at Vienna. The comparison of these remains with those e Thuringian caves is important, especially with those ɜ cave of Lindenthal near Gera, which led Liebe and Neh- ;he interesting conclusion that all this region was an exten- ren steppe, without any forest vegetation, at the begin- the Second Diluvial Period. In the cave of Vypustek are *Lynx vulgaris*, *Felis catus*, *Canis spelæus*, *C. familiaris*, *vulgaris*, *V. lagopus*, *Gulo borealis*, *Martes abietinus*, *Fœ- ıtorius*, *F. erminea*, *Vesperugo serotinus*, *Arvicola amphib-* sp., *Lepus variabilis* (*timidus?*), *Cricetus frumentarius*, *glis*, and *Sciurus vulgaris*. Besides these seventeen spe- ı Hochstetter found remains of *Elephas primigenius*, *Rhi- tichorhinus*, *Equus fossilis*, *Bos priscus*, *Cervus tarandus*, ıus, *C. capreolus*, *C. euryceros* (*?*), *Capra ibex*, *Ursus spe- əlis spelæa*, and *Hyæna spelæa;* the number of species the Vypustek Cave being therefore twenty-nine. The ɜ proves that this cave was a den of beasts of prey, long l by families of hyenas and bears, and occasionally vis- lions, lynxes and wolves; while many side galleries, some to-day, gave shelter to martens, weasels and other small ·es. Some few animals may have been carried into the er death by streams and floods; but by far the greater the remains are those of tenants of the cave, or of their ›ught in for food. The fauna of this cave indeed bears a y sylvestran character; and it may be admitted that its ; were covered with woods, and had a forest climate, at

.s the breadth of the frontal at its narrowest part when the skull is ›m above.

ıred from the anterior edge of the foramen magnum to the level of the frontal, and an inch behind it on the inside. (These measurements can, be considered only as approximations; the fragmentary condition of the ; be taken into consideration in this connection.)—J. W.

the time when northern and middle Germany had the features and climate of a steppe. Hence too the mountains and hills of South Bohemia and Moravia may be supposed to have been the center from which forests advanced gradually in every direction over the great Diluvial Steppe of Europe north of the Alpine chain. Further explorations, to be conducted by the Prehistoric Commission of the Imperial Academy of Vienna, may lead to other interesting facts as to the relative depth and succession of the animal remains in this cave.—*Nature*, July 24.

9. *Geology of Kansas;* by Professor B. F. MUDGE.—The Report of the State Board of Agriculture of Kansas, for the years 1877–8 (a volume of 632 pages, 8vo, second edition, published at Topeka, Kansas, in 1878), contains a report on the geology of the State, by Professor Mudge. It is a valuable account by one who has done much to bring the facts to light, and is accompanied by a colored geological map. The geological formations include the Drift (some of whose bowlders are of large size), Tertiary beds, Cretaceous of the Niobrara, Benton and Dakota divisions, and the Carboniferous, Sub-carboniferous and Permian. Professor Mudge collected a large part of the fossil plants from the Dakota group which have been described by Lesquereux, and also numerous new fossils among fishes and other vertebrates. The report treats also of the economical geology of the state, its gypsum, salt, lead and zinc ores, and coal.

The Agricultural Report is also in other respects a well digested and instructive volume.

10. *Geological Report of Indiana for* 1878; by E. T. Cox, assisted by Professor J. COLLETT and Dr. G. M. LEVETTE.—This new volume contains special reports on the geology of Wayne County, Harrison County, and Crawford County, besides a general Report by Professor Cox, the Report on the geological nomenclature of the Cincinnati rocks, already noticed in this Journal, a list of fossils of the rocks of the Trenton period in adjoining parts of Indiana, Ohio and Kentucky, by S. A. Miller, on Hydraulic Cements, Glacial Drift, Archæology, with a list of the Ferns, Mosses, Hepaticæ and Lichens of Wayne County, by Mrs. Haines.

11. *Genera of Felidæ and Canidæ.*—A paper on the genera of these families with important notes on some species relating principally to the fossil species, is published by Professor E. D. Cope, in the Proceedings of the Academy of Natural Sciences of Philadelphia, for 1879, commencing on page 168.

12. *The Mosasaur,* Leiodon anceps, *of the American Cretaceous.*—Professor R. Owen has a paper on the "Restoration of *Leiodon anceps*" in the Annals and Magazine of Natural History, July, 1879.

III. BOTANY.

1. *On the Origin of the Flora of the European Alps;* by JOHN BALL, F.R.S.—A lecture delivered at a meeting of the Royal Geographical Society, London, June 9, printed in its Proceedings, and separately issued as a pamphlet of 25 pages. No

one knows more than Mr. Ball of the Alpine flora, and in this lecture he discourses interestingly and very boldly upon the theoretical bearings of this extensive knowledge. His points are, that the Alpine flora did not originate in Scandinavia, but came rather from Northern Asia; that we must consider even the existing species to be very much older than the glacial period, in order to account for the actual distribution; that, since it is clear that the upper limit of Alpine vegetation is not assigned by temperature but by lack of room (upon a single ridge rising out of the Aletsch glacier, at 10,700 feet, he collected at one visit over forty flowering species), so he contends that it could not have been driven out of the Alps even by the maximum cold of the glacial period, which he supposes to have lowered the zones of vegetation only one or two thousand feet. All this will accord very well with the views taken by Saporta and not a few other naturalists. But, if we rightly understand, Mr. Ball goes on to assign an enormous antiquity—such as no one has thought of—to the existing types of phænogamous plants and to the temperate and arctic-Alpine vegetation. He supposes these to have flourished at great elevations on Paleozoic Alps at the time when the Carboniferous vegetation covered the low levels, and while the atmosphere contained twenty times as much carbonic acid as now, this gas, as he calculates, being stratified in the atmosphere according to its density, in such manner as to give to paleo-alpine plants an atmosphere and a climate not very unlike the present. He asks us to believe with him that "those humble plants that dwell in the highest region of lofty mountains, springing from crevices in the rock, or fringing with bright color the edges of the snow-field," "exempted from the vicissitudes to which the ancient vegetable world was exposed, may represent the earliest forms of the higher types of plant-life, and even that some of the species that now adorn the Alpine heights may, during the inconceivably long lapse of geologieal ages, have looked down unchanged on the revolutions that have slowly destroyed and renewed the various forms of life on the surface of our planet." A. G.

2. *The Native Plants of Victoria succinctly defined;* by Baron Ferd. von Mueller, F.R.S., etc. Part I, pp. 190, 8vo. Melbourne, 1879.—No sooner is the great *Flora Australiensis* completed, than the indefatigable Mueller sets himself to the preparation of an easy manual for the most populous colony of Victoria, and this is the first installment. It begins with the Polypetalous (Choripetalous) orders, intercalating the apetalous ones in a manner now not uncommon; it illustrates them by good wood-cut figures, with clear analyses, describes them in the simplest possible technical language, omits synonymy and also references, except those for the origination of the genus and species; and in short supplies just what is needed for educational and popular use. Let us hope that the worthy author will be encouraged and enabled to complete it. A novel peculiarity of this work is that the introduced plants are rigidly left out, even those which are overpowering the

native species. These weeds are a nuisance in every sense, to the botanist no less than to the colonist, and glad should we be everywhere to ignore them if we could. But, as a classical English poetess sings of

> "Tall Buttercups that will be seen
> Whether we will or no,"

the botanist cannot well shut his eyes to the intruders, although they do spoil the symmetry and purity of a flora. A. G.

3. *The Influence of Light on the Motions of Desmids;* by E. STAHL.—The fact that Desmids, under the influence of light, possess certain peculiar motions, was first noticed by Alexander Braun. Stahl has experimented upon species of *Closterium*, and finds that the individual *Closteria* have their longer axis parallel to the direction of the light. If placed in a glass cell, the end of the *Closterium* which is from the light attaches itself to the bottom of the cell, while the other floats freely and follows the direction of the light if it is changed. The *Closteria* undergo periodical changes of position; the floating free end toward the light finally moving backward and attaching itself to the bottom, while the end which was at first fixed becomes free. At the end of the paper, Stahl has some remarks on photometric and aphotometric swarm-spores. In a recent paper Strasburger gives the name of phototaxis to the property which swarm-spores possess of placing their long axes parallel to the direction of the light. He divides phototactic swarm-spores into photometric and aphotometric. In the latter class are included those swarm-spores which have their ciliated extremity turned toward the light. Photometric swarm-spores are those which may present either extremity toward the light. To the latter class, according to Strasburger, belong the swarm-spores of *Botrydium*. Stahl, however, maintains that the spores of *Botrydium* act like other swarm-spores, and he doubts the validity of the two forms of phototaxis as described by Strasburger. W. G. F.

4. *Development of the Prothallus of Platycerium grande;* by DR. HERMANN BAUKE.—In a paper read before the Bot. Verein of the Provinz Brandenburg, Dr. Bauke showed that the early stages of the prothallus of *Platycerium grande* differed from that of other ferns. The growth of the terminal cell of the germinal filament which comes from the spore ceases at an early period, and the cells back of it grow so as to form a peculiar membrane. From one side of this membrane shoots out a process which bears the sexual organs. In this method of growth, Dr. Bauke sees a special adaptation for the exposed place of attachment of this species, which is found very frequently on palm stems just before the terminal tuft of leaves. Dr. Bauke also discusses the dependence of the bilateral character of the fern prothallus on external forces, and assigns to gravity the principal action. In prothalli which grow vertically archegonia and rhizoids are found on both surfaces. W. G. F.

IV. Miscellaneous Scientific Intelligence.

1. *Map of the Catskill Mountains*, by A. Guyot.—Professor Guyot gives in this map the results of several summers' work in the Catskill region with his barometer and surveying instruments. He has measured the height of over two hundred places, determined by triangulation the positions of all the many summits, and discovered mountains that were not known to exist. A large part of the region, especially the southwestern, is an untracked wilderness of forests; and in several cases the only chance for making his triangulation was by climbing to the tops of the highest trees. He has found higher points than were before recorded, and many of them. His table of altitudes contains three peaks over 4,000 feet, thirteen over 3,800 feet, and thirty-six over 3,500 feet. The highest point is one of the previously unknown, Slide Mountain, in the Southern Catskills; its height is 4,205 feet above tide. An abstract of his results will appear in another number of this Journal.

The map measures 14 × 20 inches, is complete in all the topography and in geographical details, and will be of great service to tourists. It may be had in New York of Scribner's Sons and B. Westerman & Co.

2. *J. L. Campbell's "Geology of Virginia," page* 119 *of this volume.*—The following explanations of the section on page 121 were omitted in their proper places and are here inserted:—1. General bearing of the section N. 40° W. 2. Horizontal scale in miles numbered at top; vertical scale in feet numbered on right and left extremities. 3. Limestone strata are *blocked*, sandstones *dotted*, and shales *ruled*. 4. The periods and epochs are indicated, the former by *numbers*, the latter by *letters*, in accordance with the system found in Professor Dana's Manual of Geology.

3. *To Astronomers.*—The U. S. Naval Observatory, Washington, will gratefully receive for its library, *separate copies* or *reprints* of memoirs published in the Transactions of Societies or in journals. The volumes of Transactions are regularly received, but often many months after the appearance of the reprints of particular papers, which are therefore especially valued. It is also requested that all communications of this nature and correspondence relating to them may be addressed to "The Library, U. S. Naval Observatory, Washington, U. S. A."

Agents of the Smithsonian Institution abroad will receive large parcels for transmission. The smaller ones will be received more quickly if they are sent by mail.

As far as possible, the publications of the Observatory will be distributed to all working astronomers.

John Rodgers, Rear Admiral, U. S. N., Superintendent.

Washington, Aug. 18, 1879.

4. *Annual Report upon Explorations and Surveys in the Department of the Missouri*; by E. H. Ruffner, First Lieut. Eng. U. S. A.—This Report is Appendix SS (pp. 1749–1868) of the Annual Report of the Chief of Engineers for 1878. It contains a *Report on the San Juan region*, in Western Colorado and part of New Mexico, from a reconnoissance made in 1877, by Lieut. C.

A. H. McCauley, accompanied by maps and sketches. Lieut. McCauley gives an extended account of the geography, features, the various mines, agricultural and other economical resources, with some observations on the geology, the erosion and terraces along the rivers, and details as to settlements, means of communication, and proposed new lines of roads and railroads. The report is evidently the result of a careful study of the region. It also contains a classification of the Botanical Collection made by the same expedition, by Professor Asa Gray, with Notes on the Botany, by T. S. Brandegee; and an Entomological report by Professor Cyrus Thomas, which is illustrated by two plates of butterflies.

5. *Documents relative to the Origin and History of the Smithsonian Institution;* edited by Wm. J. Reeves. 1013 pp. 8vo. Washington, 1879. Smithsonian Miscellaneous Collections, 328.—The will of James Smithson, and all papers connected with his gift for the establishment of a "Smithsonian Institution" at Washington, are brought together in this volume, and also the communications which have since been made by or to the United States Government, the debates and acts relative to it, the programme of Professor Henry, and the correspondence with reference to it. The value of the Institution to the country makes everything pertaining to its history of the highest interest.

6. *On the Mode of Growth of Stromatopora;* by H. J. Carter, F.R.S., etc.—Struck with the practical nature of Mr. Champernowne's remarks on "some Devonian Stromatoporidæ from Dartington, near Totnes," published in the Quart. Journ. Geol. Soc. for February, 1879, I lost no time in putting myself in communication with him on this subject, and, having received, in reply, a kind invitation to visit the "Pit-Park Quarry" (whence his specimens had been taken), I availed myself of the opportunity on the 8th of May last.

My general inference from our visit to the Quarry was that *Stromatopora* was essentially a "reef building" organism, and that, like *Millepora alcicornis* in the West Indies, it grew profusely in its locality, not only entering and filling up the open interstices of other calcareous organisms during their growth, but enveloping their detritus (joints and stems of Encrinites, etc.), and, when not doing either of these things, growing into large masses of itself. Thus, by cementing everything together after this manner, the great reef appears to have been formed which is now known by the name of "Devonian Limestone." This is not only evidenced by the composition of the *solidified* strata generally, when cut and polished, but more convincingly and particularly by a portion of it in "Pit-Park Quarry," which, having undergone partial decomposition, now yields up its contents even more separately than probably they have ever been since they were bound together by the ubiquitous *Stromatopora.*—*From a paper in the Ann. and Mag. Nat. Hist. for August.*

7. *Möbius on Eozoon Canadense.*—A full abstract of Professor Möbius's paper on Eozoon, with illustrations copied from it, is contained in *Nature* for July 17, and 24.

Report of the Chief of Engineers for 1878. Three volumes, 8vo. Washington, 1878.

THE

AMERICAN

JOURNAL OF SCIENCE AND ARTS.

[THIRD SERIES.]

ART. XXXV.—*On Radiant Matter: A Lecture delivered to the British Association for the Advancement of Science, at Sheffield, Friday, August* 22, 1879*;* by WILLIAM CROOKES, F.R.S.

To throw light on the title of this lecture I must go back more than sixty years—to 1816. Faraday, then a mere student and ardent experimentalist, was 24 years old, and at this early period of his career he delivered a series of lectures on the General Properties of Matter, and one of them bore the remarkable title, *On Radiant Matter*. The great philosopher's notes of this lecture are to be found in Dr. Bence Jones's "Life and Letters of Faraday," and I will here quote a passage in which he first employs the expression *Radiant Matter*:—

"If we conceive a change as far beyond vaporization as that is above fluidity, and then take into account also the proportional increased extent of alteration as the changes rise, we shall perhaps, if we can form any conception at all, not fall far short of Radiant Matter; and as in the last conversion many qualities were lost, so here also many more would disappear."

Faraday was evidently engrossed with this far-reaching speculation, for three years later—in 1819—we find him bringing fresh evidence and argument to strengthen his startling hypothesis. His notes are now more extended, and they show that in the intervening three years he had thought much and deeply on this higher form of matter. He first points out that matter may be classed into four states—solid, liquid, gaseous and radiant—these modifications depending upon differences

in their several essential properties. He admits that the existence of Radiant Matter is as yet unproved, and then proceeds, in a series of ingenious analogical arguments, to show the probability of its existence.*

If, in the beginning of this century, we had asked, What is a Gas? the answer then would have been that it is matter, expanded and rarefied to such an extent as to be impalpable, save when set in violent motion; invisible, incapable of assuming or of being reduced into any definite form like solids, or of forming drops like liquids; always ready to expand where no resistance is offered, and to contract on being subjected to pressure. Sixty years ago such were the chief attributes assigned to gases. Modern research, however, has greatly enlarged and modified our views on the constitution of these elastic fluids. Gases are now considered to be composed of an almost infinite number of small particles or molecules, which are constantly moving in every direction with velocities of all conceivable magnitudes. As these molecules are exceedingly numerous, it follows that no molecule can move far in any direction without coming in contact with some other molecule. But if we exhaust the air or gas contained in a closed vessel, the number of molecules becomes diminished, and the distance through which any one of them can move without coming in contact with another is increased, the length of the mean free path being inversely proportional to the number of molecules present. The further this process is carried the longer becomes the average distance a molecule can travel before entering into

* "I may now notice a curious progression in physical properties accompanying changes of form, and which is perhaps sufficient to induce, in the inventive and sanguine philosopher, a considerable degree of belief in the association of the radiant form with the others in the set of changes I have mentioned.

"As we ascend from the solid to the fluid and gaseous states, physical properties diminish in number and variety, each state losing some of those which belonged to the preceding state. When solids are converted into fluids, all the varieties of hardness and softness are necessarily lost. Crystalline and other shapes are destroyed. Opacity and color frequently give way to a colorless transparency, and a general mobility of particles is conferred.

"Passing onward to the gaseous state, still more of the evident characters of bodies are annihilated. The immense differences in their weight almost disappear; the remains of difference in color that were left, are lost. Transparency becomes universal, and they are all elastic. They now form but one set of substances, and the varieties of density, hardness, opacity, color, elasticity and form, which render the number of solids and fluids almost infinite, are now supplied by a few slight variations in weight, and some unimportant shades of color.

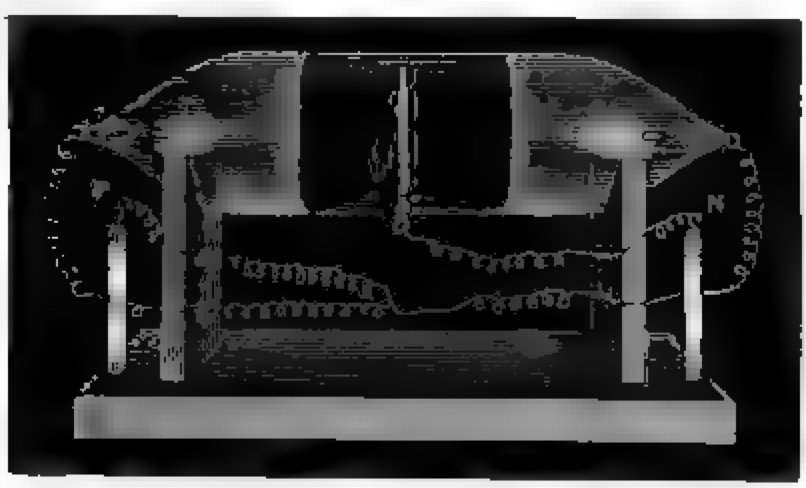
"To those, therefore, who admit the radiant form of matter, no difficulty exists in the simplicity of the properties it possesses, but rather an argument in their favor. These persons show you a gradual resignation of properties in the matter we can appreciate as the matter ascends in the scale of forms, and they would be surprised if that effect were to cease at the gaseous state. They point out the greater exertions which Nature makes at each step of the change, and think that, consistently, it ought to be greatest in the passage from the gaseous to the radiant form."—*Life and Letters of Faraday*, vol. i, p. 308.

sion; or, in other words, the longer its mean free path, the
the physical properties of the gas or air are modified.
, at a certain point, the phenomena of the radiometer
me possible, and on pushing the rarefaction still further,
decreasing the number of molecules in a given space and
thening their mean free path, the experimental results are
inable to which I am now about to call your attention.
istinct are these phenomena from anything which occurs
ir or gas at the ordinary tension, that we are led to
me that we are here brought face to face with Matter in
urth state or condition, a condition as far removed from
state of gas as a gas is from a liquid.

Mean Free Path. Radiant Matter.

have long believed that a well-known appearance observed
acuum tubes is closely related to the phenomena of the
free path of the molecules. When the negative pole is
ained while the discharge from an induction-coil is pass-
hrough an exhausted tube, a dark space is seen to sur-
d it. This dark space is found to increase and diminish
e vacuum is varied, in the same way that the mean free
of the molecules lengthens and contracts. As the one
rceived by the mind's eye to get greater, so the other is
by the bodily eye to increase in size; and if the vacuum
sufficient to permit much play of the molecules before
enter into collision, the passage of electricity shows that
"dark space" has shrunk to small dimensions. We natu-
infer that the dark space is the mean free path of the
cules of the residual gas, an inference confirmed by
riment.

1.



will endeavor to render this "dark space" visible to all
ent. Here is a tube (fig. 1), having a pole in the center
e form of a metal disk, and other poles at each end.
center pole is made negative, and the two end poles con-

nected together are made the positive terminal. The dark space will be in the center. When the exhaustion is not very great the dark space extends only a little on each side of the negative pole in the center. When the exhaustion is good, as in the tube before you, and I turn on the coil, the dark space is seen to extend for about an inch on each side of the pole.

Here, then, we see the induction spark actually illuminating the lines of molecular pressure caused by the excitement of the negative pole. The thickness of this dark space is the measure of the mean free path between successive collisions of the molecules of the residual gas. The extra velocity with which the negatively electrified molecules rebound from the excited pole keeps back the more slowly moving molecules which are advancing toward that pole. A conflict occurs at the boundary of the dark space, where the luminous margin bears witness to the energy of the discharge.

Therefore the residual gas—or, as I prefer to call it, the gaseous residue—within the dark space is in an entirely different state to that of the residual gas in vessels at a lower degree of exhaustion. To quote the words of our last year's President, in his Address at Dublin:—

"In the exhausted column we have a vehicle for electricity not constant like an ordinary conductor, but itself modified by the passage of the discharge, and perhaps subject to laws differing materially from those which it obeys at atmospheric pressure."

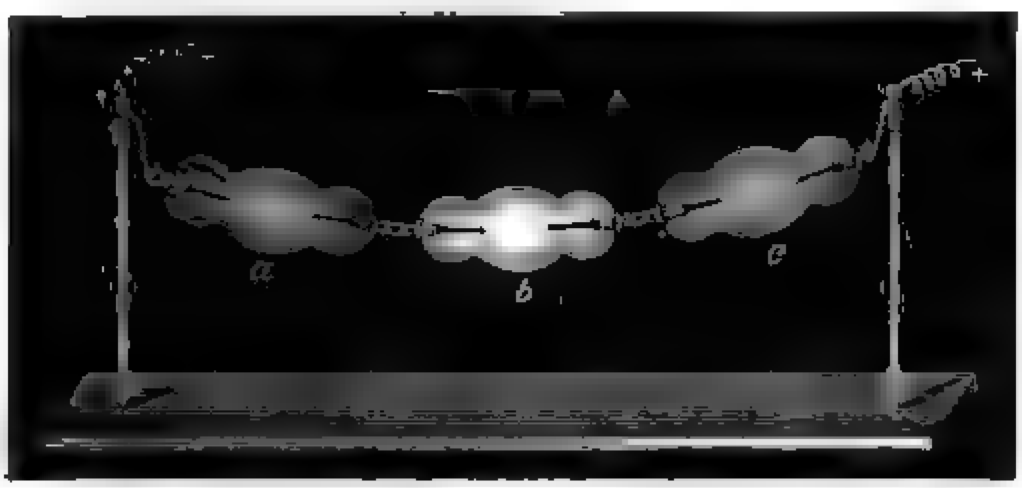
In the vessels with the lower degree of exhaustion, the length of the mean free path of the molecules is exceedingly small as compared with the dimensions of the bulb, and the properties belonging to the ordinary gaseous state of matter, depending upon constant collisions, can be observed. But in the phenomena now about to be examined, so high is the exhaustion carried that the dark space around the negative pole has widened out till it entirely fills the tube. By great rarefaction the mean free path has become so long that the hits in a given time in comparison to the misses may be disregarded and the average molecule is now allowed to obey its own motions or laws without interference. The mean free path, in fact, is comparable to the dimensions of the vessel, and we have no longer to deal with a *continuous* portion of matter, as would be the case were the tubes less highly exhausted, but we must here contemplate the molecules *individually*. In these highly exhausted vessels the molecules of the gaseous residue are able to dart across the tube with comparatively few collisions, and radiating from the pole with enormous velocity, they assume properties so novel and so characteristic as to

entirely justify the application of the term borrowed from Faraday, that of *Radiant Matter.*

Radiant Matter exerts powerful phosphorogenic action where it strikes.

I have mentioned that the Radiant Matter within the dark space excites luminosity where its velocity is arrested by residual gas outside the dark space. But if no residual gas is left, the molecules will have their velocity arrested by the sides of the glass; and here we come to the first and one of the most noteworthy properties of Radiant Matter discharged from the negative pole—its power of exciting phosphorescence when it strikes against solid matter. The number of bodies which respond luminously to this molecular bombardment is very great, and the resulting colors are of every variety. Glass, for instance, is highly phosphorescent when exposed to a stream of Radiant Matter. Here (fig. 2) are three bulbs composed of different glass: one is uranium glass (*a*), which phosphoresces of a dark green color; another is English glass (*b*), which phosphoresces of a blue color; and the third (*c*) is soft German glass,—of which most of the apparatus before you is made,—which phosphoresces of a bright apple-green.

2.

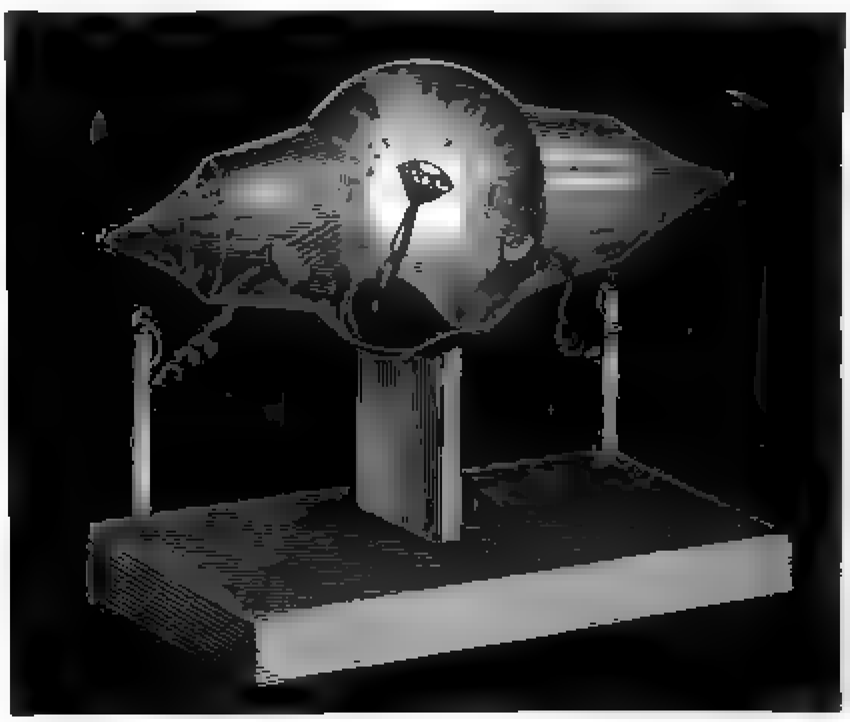


My earlier experiments were almost entirely carried on by the aid of the phosphorescence which glass takes up when it is under the influence of the radiant discharge; but many other substances possess this phosphorescent power in a still higher degree than glass. For instance, here is some of the luminous sulphide of calcium prepared according to M. Ed. Becquerel's description. When the sulphide is exposed to light—even candlelight—it phosphoresces for hours with a bluish white color. It is, however, much more strongly phosphorescent to the molecular discharge in a good vacuum, as you will see when I pass the discharge through this tube.

Other substances besides English, German, and uranium

glass, and Becquerel's luminous sulphides, are also phosphorescent. The rare mineral phenacite (aluminate of glucinum) phosphoresces blue; the mineral spodumene (a silicate of aluminium and lithium) phosphoresces a rich golden yellow; the emerald gives out a crimson light. But without exception, the diamond is the most sensitive substance I have yet met for ready and brilliant phosphorescence. Here is a very curious fluorescent diamond, green by daylight, colorless by candlelight. It is mounted in the center of an exhausted bulb (fig. 3), and the molecular discharge will be directed on it from below upward. On darkening the room you see the diamond shines with as much light as a candle, phosphorescing of a bright green.

3.



Next to the diamond the ruby is one of the most remarkable stones for phosphorescing. In this tube is a fine collection of ruby pebbles. As soon as the induction spark is turned on you will see these rubies shining with a brilliant rich red tone, as if they were glowing hot. It scarcely matters what color the ruby is, to begin with. In this tube of natural rubies there are stones of all colors—the deep red and also the pale pink ruby. There are some so pale as to be almost colorless, and some of the highly-prized tint of pigeon's blood; but under the impact of Radiant Matter they all phosphoresce with about the same color.

Now the ruby is nothing but crystallized alumina with a little coloring matter. In a paper by Ed. Becquerel,* pub-

* Annales de Chimie et de Physique, 3rd series, vol. lvii, p. 50, 1859.

lished twenty years ago, he describes the appearance of alumina as glowing with a rich red color in the phosphoroscope. Here is some precipitated alumina prepared in the most careful manner. It has been heated to whiteness, and you see it also glows under the molecular discharge with the same rich red color.

The spectrum of the red light emitted by these varieties of alumina is the same as described Becquerel twenty years ago. There is one intense red line, a little below the fixed line B in the spectrum, having a wave-length of about 6895. There is a continuous spectrum beginning at about B, and a few fainter lines beyond it, but they are so faint in comparison with this red line that they may be neglected. This line is easily seen by examining with a small pocket spectroscope the light reflected from a good ruby.

There is one particular degree of exhaustion more favorable than any other for the development of the properties of Radiant Matter which are now under examination. Roughly speaking it may be put at the millionth of an atmosphere.* At this degree of exhaustion the phosphorescence is very strong, and after that it begins to diminish until the spark refuses to pass.†

*	1·0 millionth of an atmosphere	=	0·00076 millim.
	1315·789 millionths of an atmosphere	=	1·0 millim.
	1,000,000 " " "	=	760·0 millims.
	" " " "	=	1 atmosphere.

† Nearly 100 years ago Mr. Wm. Morgan communicated to the Royal Society a Paper entitled "Electrical Experiments made to ascertain the Non-conducting Power of a Perfect Vacuum, &c." The following extracts from this Paper, which was published in the Phil. Trans. for 1785 (vol. lxxv, p. 272), will be read with interest:—

"A mercurial gage about fifteen inches long, carefully and accurately boiled till every particle of air was expelled from the inside, was coated with tin-foil five inches down from its sealed end, and being inverted into mercury through a perforation in the brass cap which covered the mouth of the cistern; the whole was cemented together, and the air was exhausted from the inside of the cistern through a valve in the brass cap, which producing a perfect vacuum in the gage formed an instrument peculiarly well adapted for experiments of this kind. Things being thus adjusted (a small wire having been previously fixed on the inside of the cistern to form a communication between the brass cap and the mercury, into which the gage was inverted) the coated end was applied to the conductor of an electrical machine, and notwithstanding every effort, neither the smallest ray of light, nor the slightest charge, could ever be procured in this exhausted gage."

"If the mercury in the gage be imperfectly boiled, the experiment will not succeed; but the color of the electric light, which in air rarefied by an exhauster is always violet or purple, appears in this case of a beautiful green, and, what is very curious, the degree of the air's rarefaction may be nearly determined by this means; for I have known instances, during the course of these experiments, where a small particle of air having found its way into the tube, the electric light became visible, and as usual of a green color; but the charge being often repeated, the gage has at length cracked at its sealed end, and in consequence the external air, by being admitted into the inside, has gradually pro-

I have here a tube (fig. 4) which will serve to illustrate the dependence of the phosphorescence of the glass on the degree of exhaustion. The two poles are at *a* and *b*, and at the end (*c*) is a small supplementary tube connected with the other by

4.

a narrow aperture, and containing solid caustic potash. The tube has been exhausted to a very high point, and the potash heated so as to drive off moisture and injure the vacuum. Exhaustion has then been re-commenced, and the alternate heating and exhaustion repeated until the tube has been brought to the state in which it now appears before you. When the induction spark is first turned on nothing is visible—the vacuum is so high that the tube is non-conducting. I now warm the potash slightly and liberate a trace of aqueous vapor. Instantly conduction commences, and the green phosphorescence flashes out along the length of the tube. I continue the heat, so as to drive off more gas from the potash. The green gets fainter, and now a wave of cloudy luminosity sweeps over the tube, and stratifications appear, which rapidly get narrower, until the spark passes along the tube in the form of a narrow purple line. I take the lamp away, and allow the potash to cool; as it cools, the aqueous vapor, which the heat had driven off, is re-absorbed. The purple line broadens out, and breaks up into fine stratifications; these get wider, and travel toward the potash tube. Now a wave of green light appears on the glass at the other end, sweeping on and driving the last pale stratification into the potash; and now the tube glows over its whole length with the green phosphorescence. I might keep it before you, and show the green growing fainter and the vacuum becoming non-conducting; but I should detain you too long, as time is required for the

duced a change in the electric light from green to blue, from blue to indigo, and so on to violet and purple, till the medium has at length become so dense as no longer to be a conductor of electricity. I think there can be little doubt, from the above experiments, of the non-conducting power of a perfect vacuum."

"This seems to prove that there is a limit even in the rarefaction of air, which sets bounds to its conducting power; or, in other words, that the particles of air may be so far separated from each other as no longer to be able to transmit the electric fluid; that if they are brought within a certain distance of each other, their conducting power begins, and continually increases till their approach also arrives at its limit."

absorption of the last traces of vapor by the potash, and I must pass on to the next subject.

Radiant Matter proceeds in straight lines.

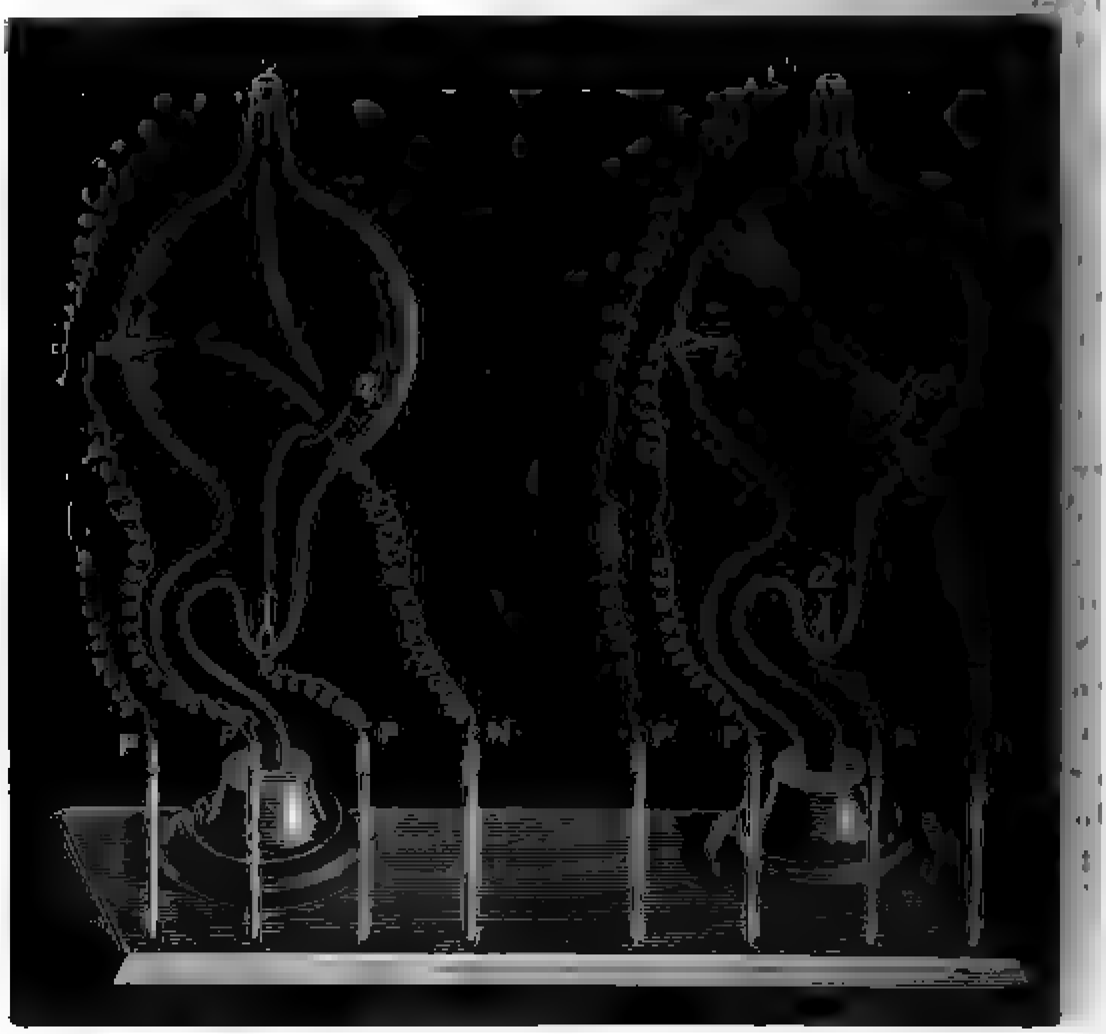
The Radiant Matter, whose impact on the glass causes an evolution of light, absolutely refuses to turn a corner. Here is a V-shaped tube, a pole being at each extremity. The pole at the right side being negative, you see that the whole of the right arm is flooded with green light, but at the bottom it stops sharply and will not turn the corner to get into the left side. When I reverse the current and make the left pole negative, the green changes to the left side, always following the negative pole and leaving the positive side with scarcely any luminosity.

In the ordinary phenomena exhibited by vacuum tubes—phenomena with which we are all familiar—it is customary, in order to bring out the striking contrasts of color, to bend the tubes into very elaborate designs. The luminosity caused by the phosphorescence of the residual gas follows all the convolutions into which skillful glass-blowers can manage to twist the glass. The negative pole being at one end and the positive pole at the other, the luminous phenomena seem to depend more on the positive than on the negative at the ordinary exhaustion hitherto used to get the best phenomena of vacuum tubes. But at a very high exhaustion the phenomena noticed in ordinary vacuum tubes when the induction spark passes through them—an appearance of cloudy luminosity and of stratifications—disappear entirely. No cloud or fog whatever is seen in the body of the tube, and with such a vacuum as I am working with in these experiments, the only light observed is that from the phosphorescent surface of the glass. I have here two bulbs (fig. 5), alike in shape and position of poles, the only difference being that one is at an exhaustion equal to a few millimeters of mercury--such a moderate exhaustion as will give the ordinary luminous phenomena—while the other is exhausted to about the millionth of an atmosphere. I will first connect the moderately exhausted bulb (A) with the induction-coil, and retaining the pole at one side (*a*) always negative, I will put the positive wire successively to the other poles with which the bulb is furnished. You see that as I change the position of the positive pole, the line of violet light joining the two poles changes, the electric current always choosing the shortest path between the two poles, and moving about the bulb as I alter the position of the wires.

This, then, is the kind of phenomenon we get in ordinary exhaustions. I will now try the same experiment with a bulb (B) that is very highly exhausted, and as before, will make

the side pole (a') the negative, the top pole (b) being positive. Notice how widely different is the appearance from that shown by the last bulb. The negative pole is in the form of a shallow cup. The molecular rays from the cup cross in the center

6.



of the bulb, and thence diverging fall on the opposite side and produce a circular patch of green phosphorescent light. As I turn the bulb round you will all be able to see the green patch on the glass. Now observe, I remove the positive wire from the top, and connect it with the side pole (c). The green patch from the divergent negative focus is there still. I now make the lowest pole (d) positive, and the green patch remains where it was at first, unchanged in position or intensity.

We have here another property of Radiant Matter. In the low vacuum the position of the positive pole is of every importance, while in a high vacuum the position of the positive pole scarcely matters at all; the phenomena seem to depend entirely on the negative pole. If the negative pole points in the direction of the positive, all very well, but if the negative pole is entirely in the opposite direction it is of little consequence: the Radiant Matter darts all the same in a straight line from the negative.

If, instead of a flat disk, a hemi-cylinder is used for the neg·ive pole, the Matter still radiates normal to its surface. The ıbe before you fig. 6) illustrates this property. It contains, as a negative pole, a hemi-cylinder (*a*) of polished aluminium. This is connected with a fine copper wire, *b*, ending at the platinum terminal, *c*. At the upper end of the tube is another terminal, *d*. The induction-coil is connected so that the hemi-cylinder is negative and the upper pole positive, and when exhausted to a sufficient extent the projection of the molecular rays to a focus is very beautifully shown. The rays of Matter being driven from the hemi-cylinder in a direction normal to its surface, come to a focus and then diverge, tracing their path in brilliant green phosphorescence on the surface of the glass.

6.

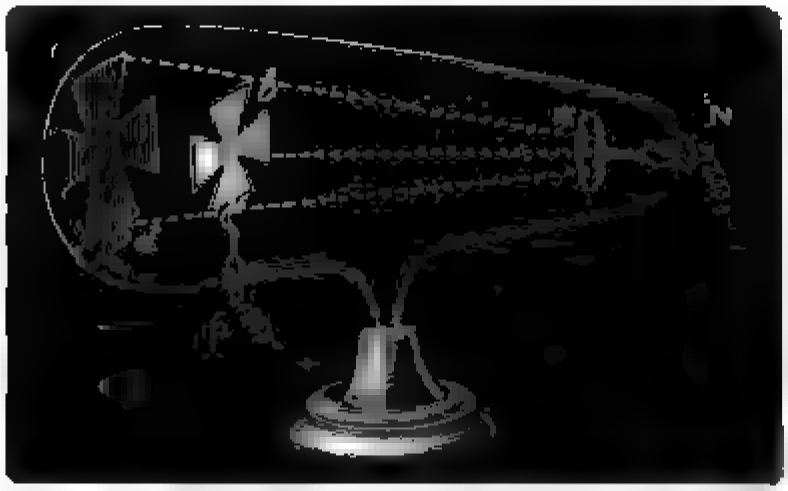
Instead of receiving the molecular rays on the glass, I will show you another tube in which the focus falls on a phosphorescent screen. See how brilliantly the lines of discharge shine out, and how intensely the focal point is illuminated, lighting up the table.

adiant Matter when intercepted by solid matter casts a shadow.

Radiant Matter comes from the pole in straight lines, and ›es not merely permeate all the parts of the tube and fill it ith light, as would be the case were the exhaustion less good. 'here there is nothing in the way the rays strike the screen ıd produce phosphorescence, and where solid matter inter›nes they are obstructed by it, and a shadow is thrown on the reen. In this pear-shaped bulb (fig. 7) the negative pole (*a*) at the pointed end. In the middle is a cross (*b*) cut out of ıeet aluminium, so that the rays from the negative pole pro›cted along the tube will be partly intercepted by the aluminm cross, and will project an image of it on the hemispherical ıd of the tube which is phosphorescent. I turn on the coil, ıd you will all see the black shadow of the cross on the minous end of the bulb (*c*, *d*). Now, the Radiant Matter om the negative pole has been passing by the side of the

aluminium cross to produce the shadow; the glass has been hammered and bombarded till it is appreciably warm, and at

7.



the same time another effect has been produced on the glass—its sensibility has been deadened. The glass has got tired, if I may use the expression, by the enforced phosphorescence. A change has been produced by this molecular bombardment which will prevent the glass from responding easily to additional excitement; but the part that the shadow has fallen on is not tired—it has not been phosphorescing at all and is perfectly fresh; therefore if I throw down this cross,—I can easily do so by giving the apparatus a slight jerk, for it has been most ingeniously constructed with a hinge by Mr. Gimingham,—and so allow the rays from the negative pole to fall uninterruptedly on to the end of the bulb, you will suddenly see the black cross change to a luminous one because the back-ground is now only capable of faintly phosphorescing, while the part which had the black shadow on it retains its full phosphorescent power. The stencilled image of the luminous cross unfortunately soon dies out. After a period of rest the glass partly recovers its power of phosphorescing, but it is never so good as it was at first.

Here, therefore, is another important property of Radiant Matter. It is projected with great velocity from the negative pole, and not only strikes the glass in such a way as to cause it to vibrate and become temporarily luminous while the discharge is going on, but the molecules hammer away with sufficient energy to produce a permanent impression upon the glass.

Radiant Matter exerts strong mechanical action where it strikes.

We have seen from the sharpness of the molecular shadows, that Radiant Matter is arrested by solid matter placed in its path. If this solid body is easily moved the impact of the molecules will reveal itself in strong mechanical action. Mr

Gimingham has constructed for me an ingenious piece of apparatus which when placed in the electric lantern will render this mechanical action visible to all present. It consists of a highly exhausted glass tube (fig. 8), having a little glass railway running along it from one end to the other. The axle of a small wheel revolves on the rails, the spokes of the wheel carrying wide mica paddles. At each end of the tube, and rather above the center, is an aluminium pole, so that whichever pole is made negative the stream of Radiant Matter darts

8.

from it along the tube, and striking the upper vanes of the little paddle-wheel causes it to turn round and travel along the railway. By reversing the poles I can arrest the wheel and send it the reverse way, and if I gently incline the tube the force of impact is observed to be sufficient even to drive the wheel up-hill.

This experiment therefore shows that the molecular stream from the negative pole is able to move any light object in front of it.

The molecules being driven violently from the pole there should be a recoil of the pole from the molecules, and by arranging an apparatus so as to have the negative pole movable and the body receiving the impact of the Radiant Matter fixed, this recoil can be rendered sensible. In appearance the apparatus (fig. 9) is not unlike an ordinary radiometer with aluminium disks for vanes, each disk coated on one side with a film of mica. The fly is supported by a hard steel instead of glass cup, and the needle point on which it works is connected by means of a wire with a platinum terminal sealed into the glass. At the top of the radiometer bulb a second terminal is sealed in. The radiometer therefore can be connected with an induction-coil, the movable fly being made the negative pole.

For these mechanical effects the exhaustion need not be so high as when phosphorescence is produced. The best pressure for this electrical radiometer is a little beyond that at which the dark space round the negative pole extends to the

sides of the glass bulb. When the pressure is only a few millims. of mercury, on passing the induction current a halo of velvety violet light forms on the metallic side of the vanes, the mica side remaining dark. As the pressure diminishes, a dark space is seen to separate the violet halo from the metal. At a pressure of half a millimeter this dark space extends to the glass, and rotation commences. On continuing the exhaustion the dark space further widens out and appears to flatten itself against the glass, when the rotation becomes very rapid.

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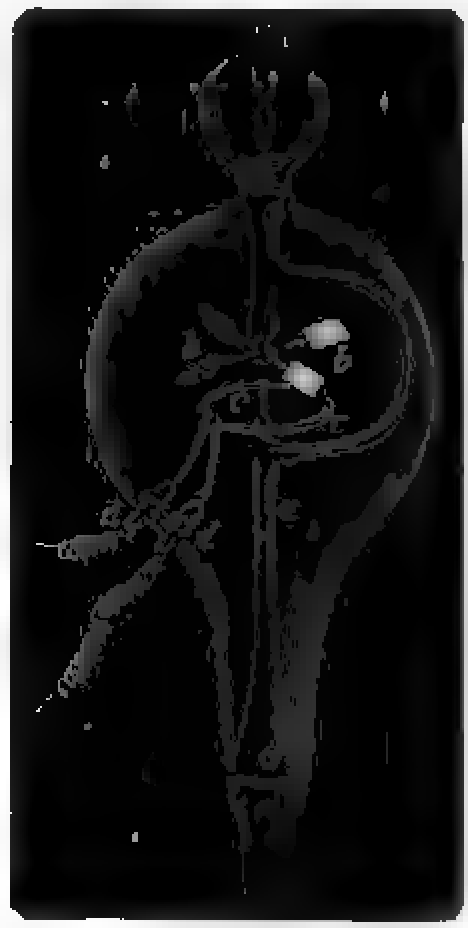


Here is another piece of apparatus (fig. 10) which illustrates the mechanical force of the Radiant Matter from the negative pole. A stem (*a*) carries a needle-point in which revolves a light mica fly (*b b*). The fly consists of four square vanes of thin clear mica, supported on light aluminium arms, and in the center is a small glass cap which rests on the needle-point. The vanes are inclined at an angle of 45° to the horizontal plane. Below the fly is a ring of fine platinum wire (*c c*), the ends of which pass through the glass at *d d*. An aluminium terminal (*e*) is sealed in at the top of the tube, and the whole is exhausted to a very high point.

By means of the electric lantern I project an image of the vanes on the screen. Wires from the induction-coil are attached, so that the platinum ring is made the negative pole,

the aluminium wire (*e*) being positive. Instantly, owing to the projection of Radiant Matter from the platinum ring, the vanes rotate with extreme velocity. Thus far the apparatus has shown nothing more than the previous experiments have prepared us to expect; but observe what now happens. I disconnect the induction-coil altogether, and connect the two ends of the platinum wire with a small galvanic battery; this makes the ring *c c* red-hot, and under this influence you see that the vanes spin as fast as they did when the induction-coil was at work.

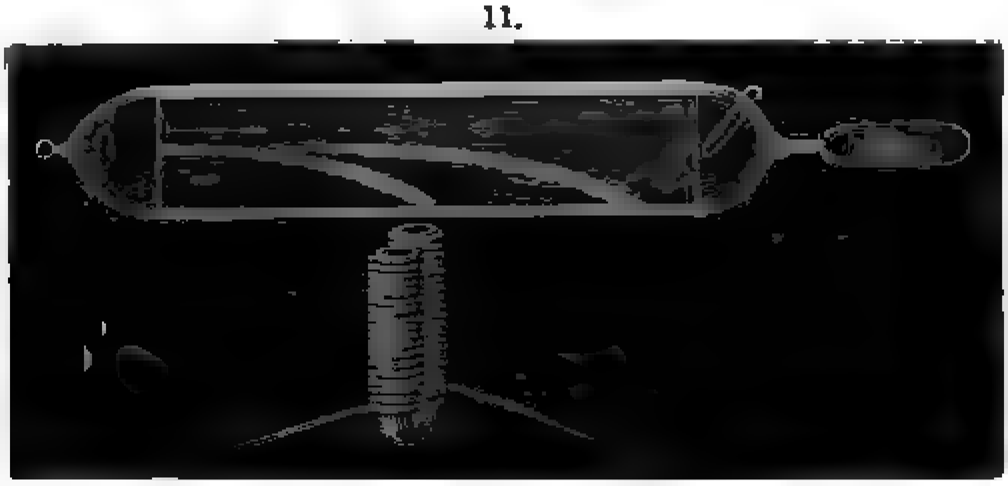
Here, then, is another most important fact. Radiant Matter in these high vacua is not only excited by the negative pole of an induction-coil, but a hot wire will set it in motion with force sufficient to drive round the sloping vanes.

Radiant Matter is deflected by a Magnet.

I now pass to another property of Radiant Matter. This long glass tube is very highly exhausted; it has a negative pole at one end and a long phosphorescent screen down the center of the tube. In front of the negative pole is a plate of mica with a hole in it, and the result is, when I turn on the current, a line of phosphorescent light is projected along the whole length of the tube. I now place beneath the tube a powerful horse-shoe magnet: observe how the line of light becomes curved under the magnetic influence waving about like a flexible wand as I move the magnet to and fro.

This action of the magnet is very curious, and if carefully followed up will elucidate other properties of Radiant Matter. Here (fig. 11) is an exactly similar tube, but having at one end a small potash tube, which if heated will slightly injure the vacuum.

11.



I turn on the induction current, and you see the ray of Radiant Matter tracing its trajectory in a curved line along the screen, under the influence of the horse-shoe magnet beneath. Observe the shape of the curve. The molecules shot from the

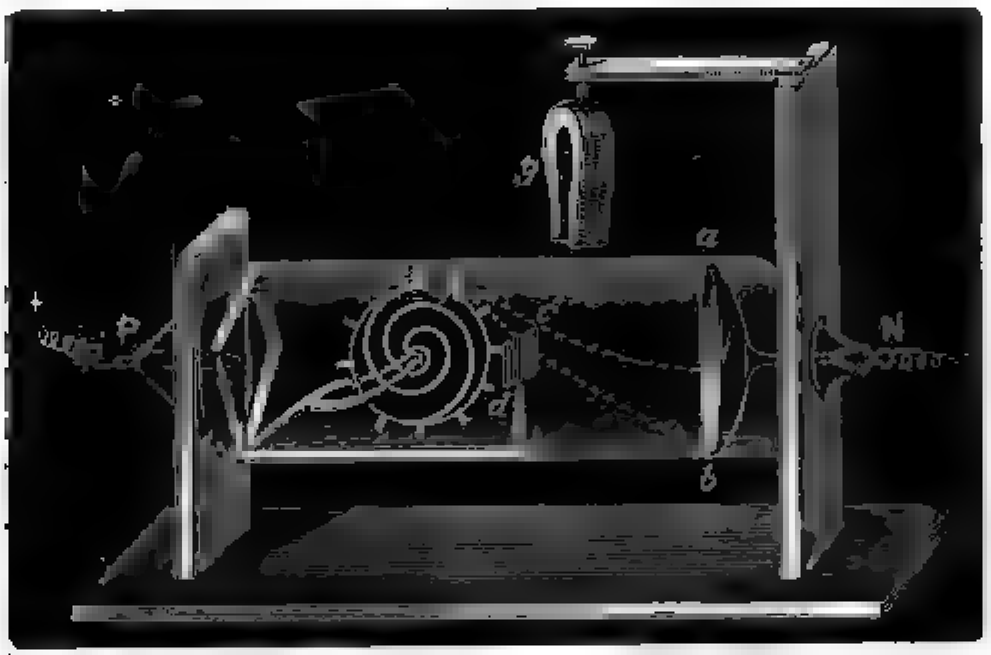
negative pole may be likened to a discharge of iron bullets from a mitrailleuse, and the magnet beneath will represent the earth curving the trajectory of the shot by gravitation. Here on this luminous screen you see the curved trajectory of the shot accurately traced. Now suppose the deflecting force to remain constant, the curve traced by the projectile varies with the velocity. If I put more powder in the gun the velocity will be greater and the trajectory flatter, and if I interpose a denser resisting medium between the gun and the target, I diminish the velocity of the shot, and thereby cause it to move in a greater curve and come to the ground sooner. I cannot well increase before you the velocity of my stream of radiant molecules by putting more powder in my battery, but I will try and make them suffer greater resistance in their flight from one end of the tube to the other. I heat the caustic potash with a spirit-lamp and so throw in a trace more gas. Instantly the stream of Radiant Matter responds. Its velocity is impeded, the magnetism has longer time on which to act on the individual molecules, the trajectory gets more and more curved, until, instead of shooting nearly to the end of the tube, my molecular bullets fall to the bottom before they have got more than half-way.

It is of great interest to ascertain whether the law governing the magnetic deflection of the trajectory of Radiant Matter is the same as has been found to hold good at a lower vacuum. The experiments I have just shown you were with a very high vacuum. Here is a tube with a low vacuum. When I turn on the induction spark, it passes as a narrow line of violet light joining the two poles. Underneath I have a powerful electro-magnet. I make contact with the magnet, and the line of light dips in the center toward the magnet. I reverse the poles, and the line is driven up to the top of the tube. Notice the difference between the two phenomena. Here the action is temporary. The dip takes place under the magnetic influence; the line of discharge then rises and pursues its path to the positive pole. In the high exhaustion, however, after the stream of Radiant Matter had dipped to the magnet it did not recover itself, but continued its path in the altered direction.

By means of this little wheel, skillfully constructed by Mr. Gimingham, I am able to show the magnetic deflection in the electric lantern. The apparatus is shown in this diagram (fig. 12). The negative pole (*a*, *b*) is in the form of a very shallow cup. In front of the cup is a mica screen (*c*, *d*), wide enough to intercept the Radiant Matter coming from the negative pole. Behind this screen is a mica wheel (*e*, *f*) with a series of vanes, making a sort of paddle-wheel. So arranged, the molecular rays from the pole *a b* will be cut off from the wheel, and will

t produce any movement. I now put a magnet, *g*, over the be, so as to deflect the stream over or under the obstacle *c d*,

12.



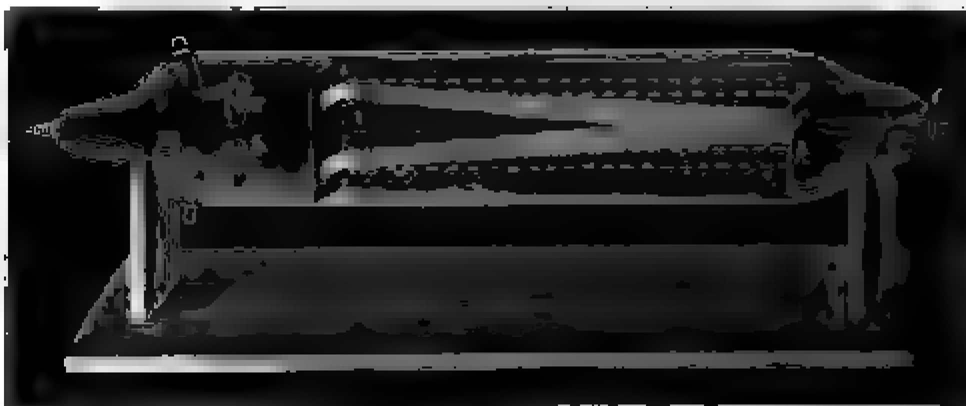
d the result will be rapid motion in one or the other direc-n, according to the way the magnet is turned. I throw the age of the apparatus on the screen. The spiral lines painted the wheel show which way it turns. I arrange the magnet draw the molecular stream so as to beat against the upper nes, and the wheel revolves rapidly as if it were an over-ɔt water-wheel. I turn the magnet so as to drive the Radiant atter underneath; the wheel slackens speed, stops, and then gins to rotate the other way, like an under-shot water-wheel. is can be repeated as often as I reverse the position of the gnet.

I have mentioned that the molecules of the Radiant Matter charged from the negative pole are negatively electrified. is probable that their velocity is owing to the mutual repul-n between the similarly electrified pole and the molecules. less high vacua, such as you saw a few minutes ago, the charge passes from one pole to another, carrying an electric rrent, as if it were a flexible wire. Now it is of great inter-; to ascertain if the stream of Radiant Matter from the nega-e pole also carries a current. Here (fig. 13) is an apparatus ich will decide the question at once. The tube contains o negative terminals (*a*, *b*) close together at one end, and one sitive terminal (*c*) at the other. This enables me to send two eams of Radiant Matter side by side along the phosphores-nt screen,—or by disconnecting one negative pole, only one eam.

If the streams of Radiant Matter carry an electric current ey will act like two parallel conducting wires and attract one

another; but if they are simply built up of negatively electrified molecules they will repel each other.

13.



I will first connect the upper negative pole (a) with the coil, and you see the ray shooting along the line d, f. I now bring the lower negative pole (b) into play, and another line (e, h) darts along the screen. But notice the way the first lien behaves; it jumps up from its first position, $d\,f$, to $d\,g$, showing that it is repelled, and if time permitted I could show you that the lower ray is also deflected from its normal direction: therefore the two parallel streams of Radiant Matter exert mutual repulsion, acting not like current carriers, but merely as similarly electrified bodies.

Radiant Matter produces heat when its motion is arrested.

During these experiments another property of Radiant Matter has made itself evident, although I have not yet drawn attention to it. The glass gets very warm where the green phosphorescence is strongest. The molecular focus on the tube, which we saw earlier in the evening (fig. 6) is intensely hot, and I have prepared an apparatus by which this heat at the focus can be rendered apparent to all present.

I have here a small tube (fig. 14, a) with a cup-shaped negative pole. This cup projects the rays to a focus in the middle of the tube. At the side of the tube is a small electromagnet, which I can set in action by touching a key, and the focus is then drawn to the side of the glass tube (fig. 14, b). To show the first action of the heat I have coated the tube with wax. I will put the apparatus in front of the electric lantern, and throw a magnified image of the tube on the screen. The coil is now at work, and the focus of molecular rays is projected along the tube. I turn the magnetism on, and draw the focus to the side of the glass. The first thing you see is a small circular patch melted in the coating of wax. The glass soon begins to disintegrate, and cracks are shooting starwise from the center of heat. The glass is softening. Now the

atmospheric pressure forces it in, and now it melts. A hole is perforated in the middle, the air rushes in, and the experiment is at an end.

I can render this focal heat more evident if I allow it to play on a piece of metal. This bulb (fig. 15) is furnished with a

14.

15.

negative pole in the form of a cup (a). The rays will therefore be projected to a focus on a piece of iridio-platinum (b) supported in the center of the bulb.

I first turn on the induction-coil slightly, so as not to bring out its full power. The focus is now playing on the metal, raising it to a white-heat. I bring a small magnet near, and you see I can deflect the focus of heat just as I did the luminous focus in the other tube. By shifting the magnet I can drive the focus up and down, or draw it completely away from the metal, and leave it non-luminous. I withdraw the magnet, and let the molecules have full play again; the metal is now white-hot. I increase the intensity of the spark. The iridio-platinum glows with almost insupportable brilliancy, and at last melts.

The Chemistry of Radiant Matter.

As might be expected, the chemical distinctions between one kind of Radiant Matter and another at these high exhaustions are difficult to recognize. The physical properties I have been elucidating seem to be common to all matter at this low density.

Whether the gas originally under experiment be hydrogen, carbonic acid, or atmospheric air, the phenomena of phosphorescence, shadows, magnetic deflection, etc., are identical, only they commence at different pressures. Other facts however, show that at this low density the molecules retain their chemical characteristics. Thus by introducing into the tubes appropriate absorbents of residual gas, I can see that chemical attraction goes on long after the attenuation has reached the best stage for showing the phenomena now under illustration, and I am able by this means to carry the exhaustion to much higher degrees than I can get by mere pumping. Working with aqueous vapor I can use phosphoric anhydride as an absorbent; with carbonic acid, potash; with hydrogen, palladium; and with oxygen, carbon, and then potash. The highest vacuum I have yet succeeded in obtaining has been the 1-20,000,000th of an atmosphere, a degree which may be better understood if I say that it corresponds to about the hundredth of an inch in a barometric column three miles high.

It may be objected that it is hardly consistent to attach primary importance to the presence of *Matter*, when I have taken extraordinary pains to remove as much Matter as possible from these bulbs and these tubes, and have succeeded so far as to leave only about the one-millionth of an atmosphere in them. At its ordinary pressure the atmosphere is not very dense, and its recognition as a constituent of the world of Matter is quite a modern notion. It would seem that when divided by a million, so little Matter will necessarily be left that we may justifiably neglect the trifling residue and apply the term *vacuum* to space from which the air has been so nearly removed. To do so, however, would be a great error, attributable to our limited faculties being unable to grasp high numbers. It is generally taken for granted that when a number is divided by a million the quotient must necessarily be small, whereas it may happen that the original number is so large that its division by a million seems to make little impression on it. According to the best authorities, a bulb of the size of the one before you (13·5 centimeters in diameter) contains more than 1,000000,000000,000000,000000 (a quadrillion) molecules. Now, when exhausted to a millionth of an atmosphere we shall still have a trillion molecules left in the bulb—a number quite sufficient to justify me in speaking of the residue as *Matter*.

To suggest some idea of this vast number I take the exhausted bulb, and perforate it by a spark from the induction coil. The spark produces a hole of microscopical fineness, yet sufficient to allow molecules to penetrate and to destroy the

vacuum. The inrush of air impinges against the vanes and sets them rotating after the manner of a windmill. Let us suppose the molecules to be of such a size that at every second of time a hundred millions could enter. How long, think you, would it take for this small vessel to get full of air? An hour? A day? A year? A century? Nay, almost an eternity! A time so enormous that imagination itself cannot grasp the reality. Supposing this exhausted glass bulb, indued with indestructibility, had been pierced at the birth of the solar system; supposing it to have been present when the earth was without form and void; supposing it to have borne witness to all the stupendous changes evolved during the full cycles of geologic time, to have seen the first living creature appear, and the last man disappear; supposing it to survive until the fulfilment of the mathematicians' prediction that the sun, the source of energy, four million centuries from its formation will ultimately become a burnt-out cinder;* supposing all this,—at the rate of filling I have just described, 100 million molecules a second—this little bulb even then would scarcely have admitted its full quadrillion of molecules.†

But what will you say if I tell you that all these molecules, this quadrillion of molecules, will enter through the microscopic hole before you leave this room? The hole being unaltered in size, the number of molecules undiminished, this apparent paradox can only be explained by again supposing the size of the molecules to be diminished almost infinitely—so that instead of entering at the rate of 100 millions every second, they troop in at a rate of something like 300 millions a second. I have done the sum, but figures when they mount so high cease to have any meaning, and such calculations are as futile as trying to count the drops in the ocean.

In studying this Fourth state of Matter we seem at length to have within our grasp and obedient to our control the little indivisible particles which with good warrant are supposed to

* The possible duration of the sun from formation to extinction has been variously estimated by different authorities, at from 18 million years to 400 million years. For the purpose of this illustration I have taken the highest estimate.

† According to Mr. Johnstone Stoney (Phil. Mag., vol. xxxvi. p. 141), 1 c.c. of air contains about 1000,000000,000000,000000 molecules. Therefore a bulb 13·5 centimeters diameter contains $13{\cdot}5^3 \times 0{\cdot}5236 \times 1000,000000,000000,000000$ or 1,288252,350000,000000,000000 molecules of air at the ordinary pressure. Therefore the bulb when exhausted to the millionth of an atmosphere contains 1,288252,350000,000000 molecules, leaving 1,288251,061747,650000.000000 molecules to enter through the perforation. At the rate of 100,000000 molecules a second, the time required for them all to enter will be

12882.510617,476500 seconds, or
214.708510,291275 minutes, or
3,578475,171521 hours, or
149103,132147 days, or
408,501731 years.

constitute the physical basis of the universe. We have seen that in some of its properties Radiant Matter is as material as this table, whilst in other properties it almost assumes the character of Radiant Energy. We have actually touched the border land where Matter and Force seem to merge into one another, the shadowy realm between Known and Unknown which for me has always had peculiar temptations. I venture to think that the greatest scientific problems of the future will find their solution in this Border Land, and even beyond; here, it seems to me, lie Ultimate Realities, subtle, far-reaching, wonderful.

> "Yet all these were, when no Man did them know,
> Yet have from wisest Ages hidden beene;
> And later Times thinges more unknowne shall show.
> Why then should witlesse Man so much misweene,
> That nothing is, but that which he hath seene?"

ART. XXXVI.—*On the Coincidence of the Bright Lines of the Oxygen Spectrum with Bright Lines in the Solar Spectrum;* by HENRY DRAPER, M.D.*

I INTEND in this paper to speak of the steps that led to the discovery of oxygen in the Sun, to describe very briefly some of the successive improvements of the electrical and optical apparatus employed, and finally to discuss the earlier results and to show their subsequent confirmation.

In 1857, after the meeting of the British Association at Dublin, some of the members, by the kindness of the Earl of Rosse, were invited to visit the 6-foot Reflector at Birr Castle. In this way I enjoyed the advantage of seeing the methods by which that great instrument had been produced, and, on returning to America in 1858, it prompted me to begin the construction of a metallic speculum of 15½ inches aperture. Soon after, by the advice of Sir John Herschel, who had early information of Foucault's work in Paris, the metal was abandoned in favor of silvered glass, and several mirrors were ground and polished. The telescope was constructed especially for photography, and good results were obtained in 1863, culminating in the production of a photograph of the Moon fifty inches in diameter. These were published in the Smithsonian Contributions to Science for the succeeding year. The success procured with this instrument prepared the way for making a silvered glass Equatoreal of twenty-eight inches aperture, which was ready for use

* Read before the Royal Astronomical Society, June 13th, 1879, and reprinted from advance sheets of the Monthly Notices. This Journal is indebted for the cuts illustrating this article, to the Astronomical Society.

in 1871, though it has been much modified since. It was obvious that increased light-collecting power and precise equatoreal movements were necessary for the modern applications of physics to astronomy. More recently still there has been attached to the same equatoreal stand an achromatic telescope of twelve inches aperture made by Alvan Clark & Sons, this being particularly intended for solar spectroscopic work.

Soon after the 28-inch Reflector was turned to stellar and planetary photographic spectroscopy it became evident that the results obtained required for their interpretation photographs of metallic and non-metallic spectra, so that comparisons might be instituted leading to precise knowledge of the elements producing lines at the more refrangible end of the spectrum. This led to a division of the work into two parts, one for the Observatory in the country in the warmer half of the year, the other for my town laboratory during the winter. It was in the latter that most of the oxygen work has been done, and consequently the engine, the Gramme machine, the induction coil, and the large spectroscope are generally there.

My first photographs of metallic spectra were taken with such apparatus as happened to be at hand, viz: a couple of Bunsen's batteries, an induction coil giving a spark of one-half inch, and a Hofmann's direct-vision spectroscope. The length of the spectrum from G to H was about half an inch, but, though the dimensions were small, the promise was great. After some experiments, however, and after obtaining more powerful instrumental appliances, it seemed best, as able physicists were engaged on the metallic spectra, to turn attention more particularly to photographing the spectra of the non-metals. The exceedingly valuable researches of Dr. Huggins had brought the astronomical importance of nitrogen, carbon and hydrogen into notice, and these accordingly were next the subject of experiment. Not long after, on examining a series of photographs of the fluted spectrum of nitrogen taken with juxtaposed solar spectra, the suspicion that there was a coincidence of some bright bands in the two spectra was suggested. On pursuing the subject with more and more powerful electrical and optical arrangements, the coincidence of bright lines of oxygen with bright lines in the solar spectrum was discovered.

The original apparatus, as has been said above, was on a very small scale, but it was soon replaced by a larger battery, a 2-inch induction coil, and a direct-vision prism of one inch aperture by Browning. The electrical part was made more and more powerful as the research proceeded, the 2-inch induction coil being succeeded by one of six inches, and that in turn by a Ruhmkorff coil capable of giving a spark of seventeen inches. The battery was eventually superseded by a Gramme dynamo-

electric machine which can produce a current powerful enough to give, between carbon points, a light equal to 500 standard candles. When this machine is properly applied to the 17-inch induction coil, it will readily give 1,000 10-inch sparks per minute. These, being condensed by fourteen Leyden jars, communicate an intense incandescence to air, and light enough is produced to permit of the use of a narrow slit, and of a collimator and telescope of long focus.

Since 1877, when the first publication of the discovery of oxygen in the Sun was made, still further improvements, especially in the optical parts, have been completed, so that I am now enabled to photograph the oxygen spectrum with four times the dispersion then employed. For the sake of clearness, it is best to give a brief description: 1st, of the electrical part; and 2nd, of the optical part.

The electrical part consists of the Gramme machine and its driving engine, the induction coil, the Leyden jars, and the terminal or spark compressor. An advantage the Gramme has over a battery is in the uniformity of the current it gives when an uniform rate of rotation of its bobbin is kept up. Of course this implies the use of a prime mover that is well regulated. The petroleum engine of one and a half horse-power I have employed is convenient and safe and does this duty well. As to the Gramme itself, it is only needful to call attention to a modification of the interior connections. In one form the bobbin of wire which revolves between the magnets is double, so that the current produced may be divided into two. Under ordinary circumstances, where the machine is used to produce light, both sides of the bobbin send their currents through the electro-magnets. But if the whole current be sent through a quick-working break circuit into an induction coil, the electro-magnets do not become sufficiently magnetised to produce any appreciable effect. It is expedient, therefore, to arrange the connections so that one-half of the bobbin gives a continuous current through the electro-magnets and keeps up the intensity of the magnetic field, and then the current from the other half of the bobbin may be used for exterior work, whether continuous or interrupted.

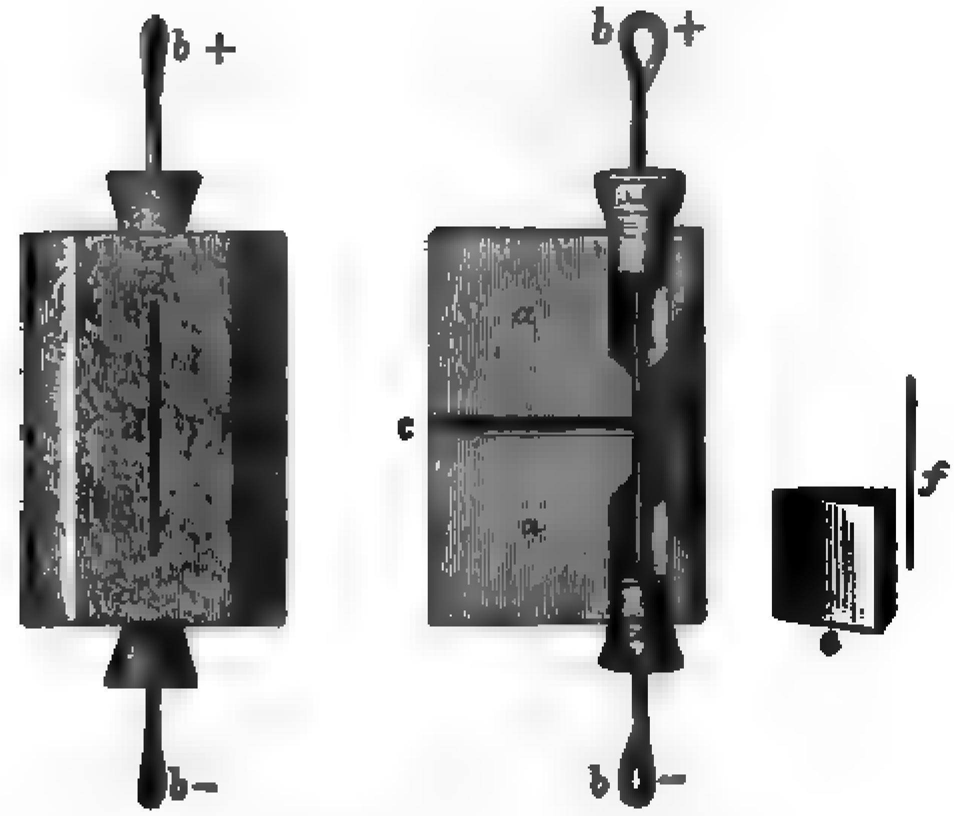
At first a Foucault mercurial interruptor was arranged to make and break the current passing into the primary circuit of the induction coil; but during the past year, by carrying the rate of rotation of the Gramme up to 1,000 per minute, the strength of the current has been so much increased that the mercury was driven violently out of the cup, and hence it was essential to arrange a mechanical break in which solid metal alone was used. This has been accomplished by fastening on the axis of the Gramme bobbin a wheel with an interrupted rim, which serves the purpose well.

As to the induction coil, it is only needful to say that it gives a good thick spark, which is limited to twelve inches to avoid the risk of injuring the insulation. The Leyden jars are fourteen in number, having altogether seven square feet of coating on each surface.

The arrangement of the terminals from the Leyden jars to get the steadiest and brightest effect has offered great difficulties. The condensed spark taken in the open air or in a gas under atmospheric pressure pursues, if unconfined, a zigzag course, and this is apt to produce a widening of the lines in the photographed spectrum. But, after many experiments, it turned out that the spark might be compressed between two plates of thick glass, or, better yet, between two plates of soapstone. If the interval between the plates was directed toward the slit of the spectroscope the lateral flickering of the spark was prevented, and yet at the same time the spark was freely exposed to the slit without the intervention of glass or any substance on which the volatilized metal from the terminals could deposit. Very early in this research it had become apparent that Plücker's tubes could not be employed with electrical currents of more than a certain intensity, partly on account of the deposit that took place in the capillary portion, and partly because the terminals became so hot as to melt and crack the glass. Moreover, it was desirable to use one terminal of iron, so as to be sure that the spectrum of the gas was correctly adjusted to the solar spectrum, and this is impracticable with Plücker's tubes. An additional advantage arises from the soapstone plates, viz: the temperature of the small volume of air between the terminals is materially increased, and increased brightness results. I have tried the effect of warming the air by passing it through a coil of brass tube maintained at a bright red heat, but this does not seem to make any perceptible difference when the terminals are enclosed in the spark compressor.

The optical part of my apparatus has undergone many modifications. At first a Hofmann direct-vision prism was combined with a lens of six inches focus; this was soon after replaced by a Browning direct-vision prism and a lens of eighteen inches focus, the latter being arranged for conjugate foci, so that it was virtually as if collimating and observing lenses of thirty-six inches focus were employed. The final system, perfected this winter, consists of a collimator of two inches aperture and twenty-six inches focus, succeeded by two bisulphide of carbon prisms of two inches aperture and an observing or photographing lens of six feet six inches focal length. These prisms belong to Mr. Rutherfurd and are the same he made for producing his celebrated solar prismatic spectrum. This gives a dispersion of about eight inches between G and H and enables

1. 2.



Spark Compressor: 1, front view; 2, section in plane of narrow openin *aa*, soapstone; *bb*, terminals; *c*, aperture for introducing gases; *d*, narrow openi to spark; *e*, right-angled prism; *f*, slit of spectroscope.

3.

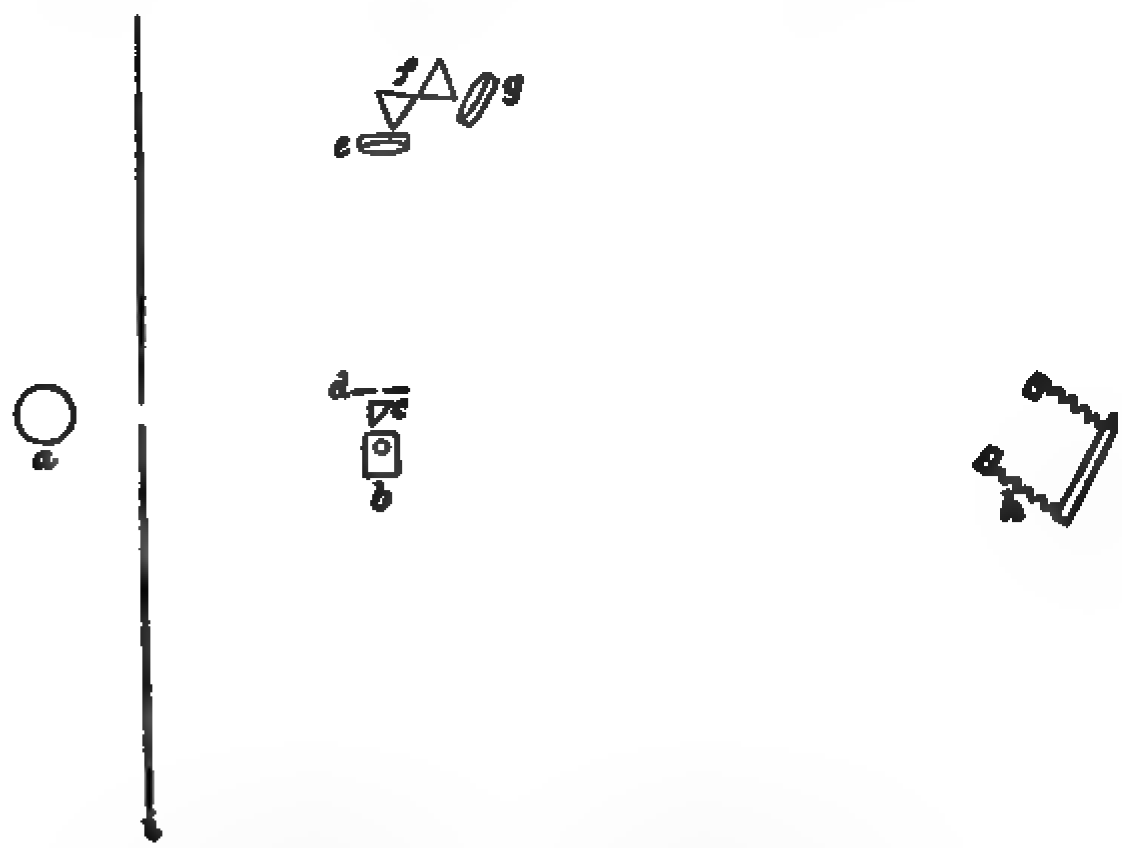


Diagram of Photographic Spectroscope: *a*, heliostat mirror; *b*, spark com pressor; *c*, right-angled prism; *d*, slit; *e*, collimator; *f*, two bisulphide prisms *g*, photographic objective; *h*, camera; *i*, window shutter.

me to get original negatives on a scale about half the size of Ångström's charts in the Spectre Normal du Soleil. When it is remembered that the light produced by the electric current in the spark compressor is scarcely equal to one standard candle, it will be realized that this great dispersion nearly attains the limit of present possibility. By comparison I have found, when the electric arc from this Gramme volatilizes iron, the light is sixty times stronger than the most vivid incandescence of air that I have produced.

The slit of the spectroscope is about one inch long, and opposite the lower half is placed a right-angled prism which serves to bring in a beam of sunlight from a heliostat. We thus have the solar spectrum and the air spectrum upon the plate at the same time, so that the two spectra on the negative are, strictly speaking, simultaneously produced. Moreover, by the aid of a magnifier we can ascertain, just previous to an exposure, whether the adjustments are in the best order. It is not commonly known that, to obtain the last degree of exactness in coincidence between a solar and an air spectrum, many precautions are necessary, and that is the reason it is desirable to have iron vapor present at one of the poles so as to determine the reliability of the coincidence by comparing iron in the spark spectrum with iron in the Sun.

Having thus alluded to some of the principal peculiarities of the apparatus constructed for this research, it is proper in the next place to point out the nature of the evidence afforded by the photographs of the presence of oxygen in the Sun. The first photographs were on so small a scale that they did not even give rise to a suspicion of this fact, and it was not until 1876 that I felt sufficiently sure to make any publication. At this time the original negatives were about two inches long from G to H, and they bore an enlargement of three or four times quite well. The Albertype printed in 1877 in Nature, the Comptes Rendus, and this Journal, was produced from such an enlargement. Since that time, in order to meet the criticism that perhaps the dispersion was not sufficient to disclose the lack of coincidence if such existed, I have increased the dispersion four times and am thus enabled to make enlarged photographs on a scale about twice the size of Ångström's chart. Enlargements of the juxtaposed spectra of air and Sun on this scale are now presented for inspection.

Of course an enlargement never does justice to the original from which it was produced, and, in order to study the matter faithfully, the negative must be examined carefully with a magnifier. Beside this, owing partly to the fact that the solar spectrum has suffered from absorptive influences, both in the Earth's atmosphere and in the solar atmosphere, the conditions

under which the oxygen spectrum is seen when compared with the spark spectrum are modified. In fact, a critical study of the two spectra demands that each line of oxygen should be separately photographed with the corresponding region of the Sun's spectrum, so as to reproduce as nearly as possible the same conditions for each. As an instance of the modifications which may be caused by the solar atmosphere, the superposition of absorption lines on the bright lines of oxygen may be mentioned. If, as seems to be the case, the stratum giving the oxygen spectrum in the Sun lies deeper than the reversing layer in which iron exists, I see no reason why an iron absorption line, for instance, may not fall upon an oxygen bright band. In support of this supposition that oxygen is photospheric, it may be stated that, though I have examined the chromosphere on many occasions, I have not as yet seen the bright oxygen lines project beyond the apparent limb of the Sun as observed in the spectroscope, although several of the chromosphere lines catalogued by Young were readily visible. On consulting with Professor Young, he expressed the opinion that the oxygen groups near G did not appear as bright lines in the chromosphere, even under the exceptionally favorable circumstances he enjoyed at Sherman. For the purpose of continuing the study of this point, and also of examining small areas on the Sun, faculæ, spots, etc., Alvan Clark & Sons are constructing a special spectroscope for me which can give the dispersion of twenty heavy flint prisms and can bear high magnifying power.

If it be conceded that there are bright lines in the spectrum of the solar disk, which seems to be the opinion of several physicists, and especially Lockyer, Cornu and Hennessy, the question of their origin naturally attracts attention. It seems that there is great probability, from general chemical reasons, that a number of the non-metals may exist in the Sun. The obvious continuation of this research is in that direction. But the subject is surrounded by exceedingly great obstacles, arising principally from the difficulty of matching the conditions as to temperature, pressure, etc., found in the Sun. Any one who has studied nitrogen, sulphur, or carbon, and has observed the manner in which the spectrum changes by variations of heat and pressure, will realize that it is well-nigh impossible to hit upon the exact conditions under which such bodies exist at the level of the photosphere. The fact that oxygen, within a certain range of variation, suffers less change than others of the non-metals has been the secret of its detection in the Sun. It appears to have a greater stability of constitution, though Schuster has shown that its spectrum may be made to vary. I have already begun an extended series of experiments on the non-metals; but the results exhibit such confusion that their

bearing cannot at present be distinctly seen. In the case of nitrogen the broad bands between G and H exhibit, under the most intense incandescence, a tendency to condense into narrow bands or lines, and indeed there are some sharp lines of nitrogen in the photographs now presented.

It does not follow, therefore, that the bright bands of oxygen are necessarily the brightest parts of the solar spectrum. Other substances may produce lines or bands of greater brilliancy.

There is also another cause for a difference of appearance in a bright-line spectrum produced in a laboratory and bright lines in the Sun. While the edges of a band in the spark spectrum may be nebulous or shaded off, the corresponding band in the solar spectrum may have its edges sharpened by the action of adjacent dark lines due to one or another of the metallic substances in the Sun.

On the whole, it does not seem improper for me to take the ground that, having shown by photographs that the bright lines of the oxygen spark spectrum all fall opposite bright portions of the solar spectrum, I have established the probability of the existence of oxygen in the Sun. Causes that can modify in some measure the character of the bright bands of the solar spectrum obviously exist in the Sun, and these, it may be inferred, exert influence enough to account for such minor differences as may be detected.

In closing, it may be well to give some idea of the amount of labor and time this research has already consumed, and this cannot be better done than by a statement of the production of electrical action that has been necessary. Each photograph demands an exposure of 15 minutes, and, with preparation and development, at least half an hour is needed. The making of a photograph, exclusive of intermediate trials, requires, therefore, about 30,000 10-inch sparks, that is 30,000 revolutions of the bobbin of the Gramme machine. In the last three years the Gramme has made 20 millions of revolutions. The petroleum engine only consumes a couple of drops of oil at each stroke, and yet it has used up about 150 gallons. Each drop of oil produces two or three 10-inch sparks. It must also be borne in mind that comparison spectra can only be made when the Sun is shining, and clouds therefore are a fertile source of loss of time.

Appendix.

[We find in the Astronomical Register a Report of the Discussion which followed the reading of Dr. Draper's paper. As this is the expression of the opinion of the best English authorities upon the conclusions reached in the memoir and as it will be seen, we suppose, by but few of our readers, we present it in pretty full abstract, as a matter of general interest.—Eds.]

After the reading of the paper, Dr. Draper showed some exquisitely sharp negatives of the solar and oxygen spectra, which he had obtained, and handed round some paper enlargements, some two feet long, for inspection by the meeting.

Mr. Ranyard: After the reception that has been given to Dr. Draper, I do not think I need say anything about the importance of the research he has undertaken. When a couple of years ago he sent over copies from his former photographs on a much smaller scale, I then ventured to say that I thought the probability of the proposition which he laid down was very great indeed, amounting to some thousands to one, and I should like now to point out how enormously the probability has been increased by these more recent experiments. If Dr. Draper has increased his dispersion four times he has not merely increased the probability of his case four times, but he has increased the value of every coincidence he shows four times. On looking at the original photographs (which show the coincidences more sharply than the paper prints) I counted eighteen oxygen lines, and, therefore, the increase of probability on the present occasion, as compared with the former occasion, is as four to the power of eighteen to one, a very enormous number. There are two or three ways of looking at the probability of the proposition which Dr. Draper has laid down, that the bright lines of oxygen coincide with the bright lines in the solar spectrum. In the first place, there is the chance that the center of no single line of oxygen should fall opposite to a dark line or space in the solar spectrum. If a line were thrown at random beside the solar spectrum the chance that it should fall opposite to a bright part of the solar spectrum would be as the total breadth of the bright part of the solar spectrum to the total breadth of the dark part of the solar spectrum. Let us suppose that the breadth occupied by dark lines in the solar spectrum is equal to the breadth occupied by bright lines (probably as seen with high dispersion this is well within the truth) then the chance of any oxygen line falling opposite to a bright line or interspace in the solar spectrum would be one-half, and if the eighteen lines of oxygen had been thrown down at random beside the solar spectrum, the chance that the center of all the lines should fall opposite to bright spaces would be one divided by two to the power of eighteen. In addition to this we must take into account the chances of the centers of the bright lines appearing to coincide with the centers of the bright interspaces where they do coincide, for in some instances the interspaces are double the breadth of the corresponding oxygen line, the oxygen line being on one side and coinciding with one edge of the interspace; but this is accounted for by the fact that there are probably other bright lines in the solar spectrum besides oxy-

gen lines, and two such bright lines happen, in some instances to fall together. Then, also, it must be remembered that the light of the bright lines of the solar spectrum has suffered absorption in the solar atmosphere, and in the earth's atmosphere, so that they may be modified by the superposition of absorption lines. The observations of the bright lines seen at the limb of the Sun renders it probable that the layer of the solar atmosphere, which gives rise to the dark lines, lies above the layer from which we receive the light of the bright oxygen spectrum, for no bright oxygen lines are seen in the chromosphere. So that it is possible to conceive that the oxygen lines of the solar spectrum may be modified as we observe them by the superposition of dark lines, and this appears in one or two instances to have been the case; but the character of the bright interspaces is very little changed. If, after examining the photographs, anybody has still any doubts as to the case made out by Dr. Draper, I think that he will feel obliged to them if they will state their objections, and give him an opportunity of discussing them.

Mr. Christie: I do not feel exactly competent to enter on this question very deeply, but Dr. Draper has very kindly given me an opportunity of examining his very beautiful photographs, and I cannot help expressing my great admiration at the splendid results he has achieved. He has obtained photographs of the spectrum of oxygen which, as far as my rather limited acquaintance with the subject goes, are far superior to anything else of the kind; but that is quite another question from proving the existence of oxygen in the Sun. I am afraid that is a very difficult question he has undertaken. If he could prove it, I think these photographs would go a very long way. I do not see myself that there is, as he has expressed it, very much more to be done in the matter. But I am sorry to say it seems to open up to me rather a hopeless prospect, because we are brought face to face with a great difficulty. Dr. Draper was very kind in explaining to me his views, and he did not at all shirk the difficulties of the case. I hope I may be justified in alluding to them, simply for the sake of getting at the truth. According to Dr. Draper's supposition, the solar spectrum is made up of a continuous spectrum with dark absorption lines, and also bright lines superposed upon it. Now, the ordinary spectrum, which up to the present time we have supposed that we had to deal with, was a continuous spectrum with dark lines, but when you superpose on this bright lines, so faint that you cannot distinguish their brightness from the general background of the spectrum, it is evident that the problem becomes more complicated. I do not want to express any opinion one way or the other. I am in the position of a sceptic; it may be

an unfortunate position, but I think it is a truly scientific position. Now, taking the position of a sceptic, one has to examine these photographs and look to whether Dr. Draper has shown the coincidences as Mr. Ranyard asserts; if not, his probabilities fall to the ground. In more than one instance I find an oxygen line opposite a broader bright space in the solar spectrum, which appears of identically the same brightness in its whole breadth. If the broader space consists of two or more bright lines, as has been suggested, we have two difficulties to contend with; in the first place we have to show that there are other substances which would give lines corresponding to the unoccupied breadth of the interspace, and in the second place we have the fact that these lines are undistinguishable in brightness from the oxygen lines. Again, each of the oxygen lines is fuzzy at the edges, and as there is nothing analogous in the solar spectrum, we have to suppose that the fuzzy edges are cut off by adjacent dark lines. Now, if we are to make use of probabilities, I would ask what is the probability of a pair of dark lines falling in every case exactly at the edges of an oxygen line? We must also take into account the fact that former physicists have failed to identify any of the bright lines of oxygen with dark lines in the solar spectrum, and therefore we start with the fact that none of the oxygen lines can fall opposite to dark lines.

Mr. Proctor said: There are one or two points I should like to mention. I do not think that Mr. Christie has sufficiently taken into account the importance of the fact that all the oxygen lines fall entirely opposite to bright interspaces in the solar spectrum, and that none of them even partially overlap dark lines. With regard to the general character of the solar spectrum, I would like to ask those who have more especially studied the subject, whether it does not seem probable from antecedent considerations that the solar spectrum should be purely gaseous in its character, that is to say, that there should be bright and dark lines, but no continuous background of spectrum. Perhaps some of you have considered the bearing of Mr. Croll's researches on this matter. He considers that the earth affords evidence that the solar system has been in existence for more than 20,000,000 of years, whereas, if the Sun has been giving out energy as at present for 20,000,000 years, we know that it cannot have derived it from shrinking from even an infinite volume to a globe as large as the photosphere. I am not inclined to agree with him in his explanation that the solar energy may in part have been derived from the impact of stars, but rather think that it points to the fact that the real mass of the Sun lies very much within the photosphere, and that if there is any solid or liquid nucleus, it is only at a depth of many thousands of miles below the photosphere. If that is

the case, I would ask whether it is antecedently probable that there should be any continuous background in the solar spectrum. If the photosphere is purely gaseous, we should only have bright bands interfered with and modified by absorption lines.

Dr. Gladstone: I have listened with the greatest attention to Dr. Draper. When the photographs first came over I was not convinced, but certainly he has produced results, which, as Mr. Ranyard has shown, have largely increased the evidence of there being real coincidences between the oxygen lines and bright spaces in the solar spectrum. There seems to be still a great question as to whether the solar spectrum is made up only of bright and dark lines, or whether there is a background of continuous spectrum. I am not disposed to give up the idea that we have a continuous spectrum underlying these dark lines, but think that it is certain that we have also bright lines mixed with the dark. We know that when we look at the edge of the Sun there are bright lines corresponding to hydrogen, and some other elements to be seen, but there are no oxygen lines. Now, I would suggest that this shows that the oxygen never rises to the level of the chromosphere, so as to be seen at the limb of the Sun, and probably that is just the reason why we see its lines as bright lines and not as dark lines, for it never gets up to a level where it is sufficiently cool to form dark lines. We can easily understand that, with so much iron and magnesium vapor, all the oxygen as it rushes upward to the higher levels may enter into combination and fall in a rain of oxides.

Dr. Huggins said that he had examined Dr. Draper's photographs, and was overwhelmed with a sense of the large amount of conscientious labor and care which he had evidently bestowed upon the investigation. Dr. Draper had made out a *primâ facie* case, which entitled him to demand a careful examination of the evidence he had brought forward; but for his own part he should like to suspend his judgment until he had had an opportunity to reëxamine that part of the spectrum. He preferred to wait for a little light, a little sunlight, on the subject, but he wished now to state how thoroughly impressed he was with the cautious and careful experimental arrangements which Dr. Draper had adopted.

Capt. Noble: It seems to me, looking at the photographs impartially, that if we are to deny the evidence supplied by some of these coincidences, and notably by this group of four lines, and accept Mr. Christie's dicta, we literally should have no tangible evidence as to the existence of any element in the Sun at all.

Mr. Ranyard: I should like to refer to one or two of the objections raised by Mr. Christie. I understood him to urge as

an objection that there are a great many bright spaces which have not been matched with the bright lines of non-metallic elements. But I would remind him that there are also many dark lines which have not been matched with the lines of known elements. Perhaps they will never be matched, for the conditions in the Sun may not correspond to the conditions obtainable in our laboratories. With regard to the bright lines falling opposite interspaces which are broader than the bright lines of oxygen, the probability is, as Mr. Christie states, very great against their being two adjacent bright lines of exactly equal brightness, but it must be remembered that we are not examining the bright lines themselves, but only photographs of the lines, and that the bright parts of these photographs are what would be called by photographers over-exposed, and, consequently, the gradations of brightness are very much obliterated. Again, I understood Mr. Christie to say that if, instead of matching oxygen lines with interspaces, you began the other way, you ought to find the brightest lines of the spectrum matching the oxygen lines, but this involves the assumption that oxygen gives brighter lines than any other element in the Sun. But I would ask what reason we have for assuming that oxygen gives brighter lines than any other element? With regard to the probability of there being a continuous background of brightness in the solar spectrum, it should be remembered that there are theoretical considerations which render it probable that there is always such a continuous background more or less faint between the bright lines in the spectrum of a gas—when the pressure is considerable the brightness of the continuous part of the spectrum is conspicuous; but theoretically there will always be a continuous spectrum corresponding to the short interval of time after the impact of molecules during which the jar of the collision lasts. In the free path between the impacts they give out the characteristic wave lengths, but however rare the gas I suppose there will always be some continuous spectrum corresponding to the impacts, and with the spectra of a great many gaseous elements superposed the continuous spectrum may be conspicuous. We need not, therefore, assume if we should find evidence of such a continuous spectrum that there is any solid or liquid matter in the photosphere; and if it should turn out that there are no oxygen lines above the photosphere, it will not, I think, follow that there is no oxygen there, for there seems to be evidence that the spectrum of some of the elements changes materially at different altitudes, for example, the 1474 line is the brightest of the bright lines in the corona, but it is a very faint line at the level of the reversing layer, and D_3 is a very bright line in the lower chromosphere, but there is no dark line corresponding to it.

Mr. Christie: I should not have risen except that reference had been made to my remarks. I do not know that I should say very much, but I think I may remark with reference to this question of coincidence, that everything turns upon the exactness of the coincidence, and whether these are actually coincidences or not. I am not quite prepared to admit that these coincidences are perfect; in fact, I should say there are even coincidences of dark lines with some of the oxygen lines. I admit that it is a matter of judgment, and I should be sorry to say positively that there are such coincidences with dark lines. But there is considerable uncertainty in the matter. As Dr. Draper has explained there is a great difficulty in establishing coincidences, and you have to adjust your apparatus until you match coincidences by the known lines of iron. It seems some of these do not coincide exactly with the dark lines in the sun. I only alluded to that as being one of the difficulties we have to contend with. With regard to Mr. Ranyard's remarks as to the eye perceiving differences of brightness which the photographs do not show, I would merely wish to ask whether he has examined with his eye different parts of the spectrum, for there is a certain part in the neighborhood of the G lines which I have examined and find the photograph gives exactly the same appearance as is seen with the eye, i. e., the whole space is of equal intensity. I do not think there is much difference between the photograph and the spectrum as seen with the eye. The only object of my remarks was to clear the ground and to point out what it is we are assuming when we predicate the existence of oxygen as giving bright lines in the sun. I do not dispute it, but only point out the difficulties we must face in order that they may be fairly met.

Mr. J. Rand Capron: There is one question I should like to ask Dr. Draper, and that is, whether he had tried any experiments with the tube spectrum of oxygen?

Dr. Draper: A great many.

Mr. J. Rand Capron: The spark taken in air would probably hardly agree with the spectrum of oxygen near the sun's body. I have had occasion to photograph simultaneously the tube spectrum of hydrogen and the air spark spectrum at ordinary pressures. The tube spectrum of hydrogen showed four hydrogen lines perfect throughout, but only one of these lines was represented in the spectrum of air at ordinary pressure, so that it is possible certain oxygen lines present in the sun may be absent in the spark spectrum.

Dr. Draper: I have taken the oxygen spectrum under a great many different circumstances. I began with tubes containing oxygen and compounds of oxygen, but the difficluty is that you are limited to rather small dispersion, because you cannot get

brightness enough for a larger apparatus. Then the difficulty of having iron terminals so as to show a good coincidence is a serious one. So when I made the spark-compressor I arranged a contrivance at the back which would enable me to let in oxygen and the other gases between the terminals, and after various experiments with oxygen I find that it seems to suffer less change with altered conditions than a great many of the other elements I have experimented on. I have fairly shown that the bright lines coincide with bright spaces in the solar spectrum. The minor differences may be fairly attributed to such changes of condition as Mr. Rand Capron has referred to. With regard to Dr. Gladstone's remark, which was that probably we should not find in the chromosphere the lines of the oxygen spectrum. That is precisely what I hope will be the case, although I am going to look as hard as I can for them. I should like to see them if they are there, but I shall be better satisfied if they are not.

A cordial vote of thanks was then passed to Dr. Draper.

[The photographs of the oxygen spectrum and juxtaposed solar spectrum, were also presented to the French Academy of Sciences in Paris, at the meeting of June 23, 1879, by M. A. Cornu. M. Faye made the following remarks, which we translate from the Comptes Rendus.—EDS.]

"I cannot refrain from adding some words to the brilliant communication that the Academy has just heard. Everything leads us to believe that the constitution of the photosphere and its marvellous alimentation, are due to alternate phenomena of chemical combination and dissociation operating at divers temperatures in the mass of the Sun under the influence of ascending and descending vertical movements. Such at least is the idea I have arrived at, by the study of spots, of the problem which I think I have presented in all its fulness. Naturally, the richness in oxygen of the compounds which constitute the earth's crust, though the proportion diminishes little by little as we descend, ought to cause us to believe that this same element should play an analogous part in the Sun; but it is a remarkable thing that up to the present, spectrum analysis has not given any trace of it. On the other hand, it showed that round that star there was a vast atmosphere of hydrogen almost pure and very much rarified, of which certain portions, frequently drawn downward by the mechanical action of solar whirlwinds, gave origin, in ascending again, to the phenomena of the protuberances.

Mr. H. Draper has, however, succeeded in discovering the oxygen, not in the chromosphere, but in the photosphere, where it discloses itself by bright lines. It is obvious that if this gas

is dissociated at a depth, it is immediately taken up by multiple combinations in the region and at the temperature of the brilliant surface. I see in these facts the hope of a confirmation and above all of an extension of the views I have put forth on the constitution of the Sun; but whatever may be the fate that the progress of spectrum analysis reserves to them, I express here my admiration for the discovery of Mr. Draper, and I hope that his results, so well confirmed by the photographic proofs that our learned member M. Cornu has shown to the Academy, will not delay in being universally accepted by competent judges."

ART. XXXVII.—*On the Vapor-Densities of Peroxide of Nitrogen, Formic Acid, Acetic Acid, and Perchloride of Phosphorus;* by J. WILLARD GIBBS.

THE relation between temperature, pressure, and volume, for the vapor of each of these substances differs widely from that expressed by the usual laws for the gaseous state,—the laws known most widely by the names of Mariotte, Gay-Lussac, and Avogadro. The *density* of each vapor, in the sense in which the term is usually employed in chemical treatises, i. e., its density taken relatively to air of the same temperature and pressure,* has not a constant value, but varies nearly in the ratio of one to two. And these variations are exhibited at pressures not exceeding that of the atmosphere and at temperatures comprised between zero and 200° or 300° of the centigrade scale.

Such anomalies have been explained by the supposition that the vapor consists of a mixture of two or three different kinds of gas or vapor, which have different densities. Thus it is supposed that the vapor of peroxide of nitrogen is a gas-mixture, the components of which are represented (in the newer chemical notation) by NO_2 and N_2O_4 respectively. The densities corresponding to these formulæ are 1·589 and 3·178. The density of the mixture should have a value intermediate between these numbers, which is substantially the case with the actual vapor. The case is similar with respect to the vapor of formic acid, which we may regard as a mixture of CH_2O_2 (density 1·589) and $C_2H_4O_4$ (density 3·178), and the vapor of acetic acid, which we may regard as a mixture of $C_2H_4O_2$ (density 2·073) and $C_4H_8O_4$ (density 4·146). In the case of perchloride of phosphorus, we must suppose the vapor to consist of three parts; PCl_5 (the proper perchloride, density 7·20), PCl_3 (the protochloride, density 4·98), and Cl_2 (chlorine, density 2·22). Since the chlorine and protochloride arise from the decom-

* The language of this paper will be conformed to this usage.

position of the perchloride, there must be as many molecules of the type Cl_2 as of the type PCl_3. Now a gas-mixture containing an equal number of molecules of PCl_3 and Cl_2 will have the density $\frac{1}{2}(4{\cdot}98+2{\cdot}22)$ or 3·60. It follows that at least so far as the range of the possible values of its density is concerned, we may regard the vapor as a mixture in variable proportions of two kinds of gas having the densities 7·20 and 3·60 respectively. The observed values of the density accord with this supposition.

These hypotheses respecting the constitution of the vapors are corroborated, in the case of peroxide of nitrogen and perchloride of phosphorus, by other circumstances. The varying color of the first vapor may be accounted for by supposing that the molecules of the type N_2O_4 are colorless, while each molecule of the type NO_2 has a constant color. This supposition affords a simple relation between the density of the vapor and the depth of its color, which has been verified by experiment.*

The vapor of the perchloride of phosphorus shows with increasing temperature in an increasing degree the characteristic color of chlorine. The amount of the color appears to be such as is required by the hypothesis respecting the constitution of the vapor on the very probable supposition that the perchloride proper is colorless, but the case hardly admits of such exact numerical determinations as are possible with respect to the peroxide of nitrogen.† But since the products of dissociation are in this case dissimilar, they may be partially separated by diffusion through a neutral gas, the lighter chlorine diffusing more rapidly than the heavier protochloride. The fact of dissociation has in this way been proved by direct experiment.‡

In the case of acetic and formic acids, we have no other evidence than the variations of the densities in support of the hypothesis of the compound nature of the vapor, yet if these variations shall appear to follow the same law as those of the peroxide of nitrogen and the perchloride of phosphorus, it will be difficult to refer them to a different cause.

But however it may be with these acids, the peroxide of nitrogen and the perchloride of phosphorus evidently furnish us with the means of studying the laws of chemical equilibrium in gas-mixtures in which chemical change is possible and does in fact take place, reversibly, with varying conditions of temperature and pressure. Or, if from any considerations we can deduce a general law determining the proportions of the

* Salet, "Sur la coloration du peroxyde d'azote." Comptes Rendus, t. lxvii, p. 488.

† H. Sainte-Claire Deville, "Sur les densités de vapeur." Comptes Rendus, t. lxii, p. 1157.

‡ Wanklyn and Robinson. "On Diffusion of Vapours: a means of distinguishing between apparent and real Vapour-densities of Chemical Compounds. Proc. Roy. Soc., vol. xii, p. 507.

component gases necessary for the equilibrium of such a mixture under any given conditions, these substances afford an appropriate test for such a law.

In a former paper* by the present writer, equations were proposed to express the relation between the temperature, the pressure or the volume, and the quantities of the components in such a gas-mixture as we are considering—a *gas-mixture of convertible components* in the language of that paper. Applied to the vapor of the peroxide of nitrogen, these equations led to a formula giving the density in terms of the temperature and pressure, which was shown to agree very closely with the experiments of Deville and Troost, and much less closely, but apparently within the limits of possible error, with the experiments of Playfair and Wanklyn. Since the publication of that paper, new determinations of the density have been published in different quarters, which render it possible to compare the equation with the results of experiment throughout a wider range of temperature and pressure. In the present paper, all experimental determinations of the density of this vapor which have come to the knowledge of the writer are cited, and compared with the values demanded by the formula, and a similar comparison of theory and experiment is made with respect to each of the other substances which have been mentioned.

The considerations from which these formulæ were deduced may be briefly stated as follows. It will be observed that they are based rather upon an extension of generally acknowledged principles to a new class of cases than upon the introduction of any new principle.

The energy of a gas-mixture may be represented by an expression of the form

$$m_1(c_1 t + E_1) + m_2(c_2 t + E_2) + \text{etc.},$$

with as many terms as there are different kinds of gas in the mixture, m_1, m_2, etc., denoting the quantities (by weight) of the several component gases, c_1, c_2, etc., their several specific heats at constant volume, E_1, E_2, etc., other constants, and t the absolute temperature. In like manner the entropy of the gas-mixture is expressed by

$$m_1\left(H_1 + c_1 \log_N t - a_1 \log_N \frac{m_1}{v}\right) + m_2\left(H_2 + c_2 \log_N t - a_2 \log_N \frac{m_2}{v}\right) + \text{etc.},$$

* "On the Equilibrium of Heterogeneous Substances." Transactions of the Connecticut Academy, vol. iii, p. 108. The equations referred to are (313), (317), (319) and (320), on pages 233 and 234. The applicability of these equations to such cases as we are now considering is discussed under the heading "Gas-mixtures with Convertible Components," page 234.

where v denotes the volume, and H_1, a_1, H_2, a_2, etc., denote constants relating to the component gases, a_1, a_2, etc., being inversely proportional to their several densities. The logarithms are Naperian. These expressions for energy and entropy will undoubtedly apply to mixtures of different gases, whatever their chemical relations may be, (with such limitations and with such a degree of approximation as belong to other laws of the gaseous state), when no chemical action can take place under the conditions considered. If we assume that they will apply to such cases as we are now considering, although chemical action is possible, and suppose the equilibrium of the mixture with respect to chemical change to be determined by the condition that its entropy has the greatest value consistent with its energy and its volume, we may easily obtain an equation between m_1, m_2, etc., t and v.*

The condition that the energy does not vary, gives

$$(m_1 c_1 + m_2 c_2 + \text{etc.})\, dt + (c_1 t + E_1)\, dm_1 + (c_2 t + E_2)\, dm_2 + \text{etc.} = 0. \quad (1)$$

The condition that the entropy is a maximum implies that its variation vanishes, when the energy and volume are constant: this gives

$$\frac{m_1 c_1 + m_2 c_2 + \text{etc.}}{t}\, dt + \left(H_1 - a_1 + c_1 \log_N t - a_1 \log_N \frac{m_1}{v}\right) dm_1 + \left(H_2 - a_2 + c_2 \log_N t - a_2 \log_N \frac{m_2}{v}\right) dm_2 + \text{etc.} = 0. \quad (2)$$

Eliminating dt, we have

$$\left(H_1 - a_1 - c_1 - \frac{E_1}{t} + c_1 \log_N t - a_1 \log_N \frac{m_1}{v}\right) dm_1 + \left(H_2 - a_2 - c_2 - \frac{E_2}{t} + c_2 \log_N t - a_2 \log_N \frac{m_2}{v}\right) dm_2 + \text{etc.} = 0. \quad (3)$$

If the case is like that of the peroxide of nitrogen, this equation will have two terms, of which the second may refer to the denser component of the gas-mixture. We shall then have $a_1 = 2a_2$, and $dm_1 = -dm_2$, and the equation will reduce to the form

$$\log \frac{m_2 v}{m_1^2} = -A - B \log t + \frac{C}{t}, \quad (4)$$

where common logarithms have been substituted for Naperian, and A, B and C are constants. If, in place of the quantities of the components, we introduce the partial pressures, p_1, p_2, due to these components, and measured in millimeters of mercury, by means of the relations

* For certain *a priori* considerations which give a degree of probability to these assumptions, the reader is referred to the paper already cited.

$$m_1 = \frac{p_1 v}{\alpha_1 t}, \qquad m_2 = \frac{p_2 v}{\frac{1}{2}\alpha_1 t},$$

where α_1 denotes a constant, we have

$$\log\frac{p_2}{p_1^2} = -(\mathrm{A} + \log 2\,\alpha_1) - (1 + \mathrm{B})\log t + \frac{\mathrm{C}}{t}$$

$$= -\mathrm{A}' - \mathrm{B}'\log t + \frac{\mathrm{C}}{t}, \tag{5}$$

where A′ and B′ are new constants. Now if we denote by p the total pressure of the gas-mixture (in millimeters of mercury), by D its density (relative to air of the same temperature and pressure), and by D_1 the theoretical density of the rarer component, we shall have

$$p : p + p_2 :: \mathrm{D}_1 : \mathrm{D}.$$

This appears from the consideration that $p+p_2$ represents what the pressure would become, if without change of temperature or volume all the matter in the gas-mixture could take the form of the rarer component. Hence,

$$p_2 = p\,\frac{\mathrm{D} - \mathrm{D}_1}{\mathrm{D}_1},$$

$$p_1 = p - p_2 = p\,\frac{2\,\mathrm{D}_1 - \mathrm{D}}{\mathrm{D}_1},$$

and

$$\frac{p_2}{p_1^2} = \frac{\mathrm{D}_1(\mathrm{D} - \mathrm{D}_1)}{p\,(2\,\mathrm{D}_1 - \mathrm{D})^2}.$$

By substitution in (5) we obtain

$$\log\frac{\mathrm{D}_1(\mathrm{D} - \mathrm{D}_1)}{(2\,\mathrm{D}_1 - \mathrm{D})^2} = -\mathrm{A}' - \mathrm{B}'\log t + \frac{\mathrm{C}}{t} + \log p_1. \tag{6}$$

By this formula, when the values of the constants are determined, we may calculate the density of the gas-mixture from its temperature and pressure. The value of D_1 may be obtained from the molecular formula of the rarer component. If we compare equations (3), (4) and (5), we see that

$$\mathrm{B}' = \mathrm{B} + 1, \qquad \mathrm{B} = \frac{c_1 - c_2}{a_2}.$$

Now $c_1 - c_2$ is the difference of the specific heats at constant volume of NO_2 and N_2O_4. The general rule that the specific heat of a gas at constant volume and per unit of weight is independent of its *condensation*, would make $c_1 = c_2$, $\mathrm{B}=0$, and $\mathrm{B}'=1$. It may easily be shown, with respect to any of the substances considered in this paper,* that unless the numerical value of B′ greatly exceeds unity, the term $\mathrm{B}'\log t$ may be neglected without serious error, if its omission is compensated

* For the case of peroxide of nitrogen, see pp. 243, 244 in the paper cited above.

in the values given to A′ and C. We may therefore cancel this term, and then determine the remaining constants by comparison of the formula with the results of experiment.

In the case of a mixture of Cl_2, PCl_3 and PCl_5, equation (3) will have three terms distinguished by different suffixes. To fix our ideas, we may make these suffixes $_2$, $_3$ and $_5$, referring to Cl_2, PCl_3 and PCl_5 respectively. Since the constants a_2, a_3 and a_5 are inversely proportional to the densities of these gases,

$$a_2\, dm_2 = a_3\, dm_3 = -\, a_5\, dm_5,$$

and we may substitute $\frac{1}{a_2}$, $\frac{1}{a_3}$, $\frac{-1}{a_5}$ for dm_2, dm_3 and dm_5 in equation (3), which is thus reduced to the form

$$\log \frac{m_5\, v}{m_2\, m_3} = -\mathrm{A} - \mathrm{B} \log t + \frac{\mathrm{C}}{t}. \tag{7}$$

If we eliminate m_2, m_3, m_5 by means of the partial pressures, p_2, p_3, p_5, we obtain

$$\log \frac{p_5}{4 p_2 p_3} = -\mathrm{A}' - \mathrm{B}' \log t + \frac{\mathrm{C}}{t}, \tag{8}$$

when A′, B′, like A, B and C, are constants. If the chlorine and the protochloride are in such proportions as arise from the decomposition of the perchloride, $p_2 = p_3$ and $4p_2p_3 = (p_2 + p_3)^2$. In this case, therefore, we have

$$\log \frac{p_5}{(p_2 + p_3)^2} = -\mathrm{A}' - \mathrm{B}' \log t + \frac{\mathrm{C}}{t}. \tag{9}$$

It will be seen that this equation is of the same form as equation (5), when p_5 in (9) is regarded as corresponding to p_2 in (5), and $p_2 + p_3$ in (9), which represents the pressure due to the products of decomposition, is regarded as corresponding to p_1 in (5), which has the same signification. It follows that equation (5), as well as (6), which is derived from it, may be regarded as applying to the vapor of perchloride of phosphorus, when the values of the constants are properly determined. This result might have been anticipated, but the longer course which we have taken has given us the more general equations, (7) and (8), which will apply to cases in which there is an excess of chlorine or of the protochloride.

If the gas-mixture considered, in addition to the components capable of chemical action, contains a neutral gas, the expressions for the energy and entropy of the gas-mixture should properly each contain a term relating to this neutral gas. This would make it necessary to add $c_n m_n$ to the coefficient of dt in (1), and $\frac{c_n m_n}{t}$ to the coefficient of dt in (2), the suffix $_n$ being

used to mark the quantities relating to the neutral gas. But these quantities would disappear with the elimination of dt, and equation (3) and all the subsequent equations would require no modification, if only p and D are estimated (in accordance with usage) with exclusion of the pressure and weight due to the neutral gas. This result, which may be extended to any number of neutral gases, is simply an expression of Dalton's Law.

We now proceed to the comparison of the formulæ, especially of equation (6), with the results of experiment.

Table I.—Peroxide of Nitrogen.

Experiments at Atmospheric Pressure.

Mitscherlich,—R. Müller,—Deville and Troost.

Temperature.	Pressure.	Density calc. by eq. (10).	Density observed. M—h. M—r.	Density observed. Deville & Troost. I.	II.	III.	Excess of observed density. M—h, M—r.	Excess of observed density. Deville & Troost. I.	II.	III.
183·2	(760)	1·592				1·57				—·022
154·0	(760)	1·597				1·58				—·017
151·8	(760)	1·598		1·50				—·10		
135·0	(760)	1·607				1·60				—·007
121·8	(760)	1·622		1·64				+·02		
121·5	(760)	1·622				1·62				—·002
111·3	(760)	1·641				1·65				+·009
100·25	760	1·677	1·72				+·04			
100·1	(760)	1·676				1·68				+·004
100·0	(760)	1·677		1·71				+·03		
90·0	(760)	1·728				1·72				—·008
84·4	(760)	1·768		1·83				+·06		
80·6	(760)	1·801				1·80				—·001
79	748	1·814	1·84				+·03			
77·4	(760)	1·833			1·85				+·02	
70·0	(760)	1·920				1·92				·000
70	754·5	1·919	1·95				+·03			
68 8	(760)	1·937		1·99				+·05		
66·0	(760)	1·976			2·03				+·05	
60·2	(760)	2·067				2·08				+·013
55·0	(760)	2·157			2·20				+·04	
52	757	2·211	2·26				+·05			
49·7	(760)	2·255		2·34				+·09		
49·6	(760)	2·256				2·27				+·014
45·1	(760)	2·342			2·40				+·06	
39·8	(760)	2·443				2·46				+·017
35·4	(760)	2·524				2·53				+·006
35·2	(760)	2·528		2·66				+·13		
34·6	(760)	2·539			2·62				+·08	
32	748	2·582	2·65				+·07			
28·7	(760)	2·642		2·80				+·16		
28	751	2·652	2·70				+·05			
27·6	(760)	2·661			2·70				+·04	
26·7	(760)	2·676				2·65				—·026

Peroxide of nitrogen.—If we take the constants of the equation for this substance from the paper already cited,* we have

$$\log \frac{15{\cdot}89\,(D - 1{\cdot}589)}{(3{\cdot}178 - D)^2} = \frac{3118{\cdot}6}{t_C + 273} + \log p - 12{\cdot}451, \qquad (10)$$

t_C denoting the temperature on the centigrade scale. The numbers 3·178 and 1·589 represent the theoretical densities of N_2O_4 and NO_2 respectively. The two other constants were determined by the experiments of Deville and Troost.

The results of these and other experiments at atmospheric pressure, all made by Dumas' method, are exhibited in Table I. The first three columns give the temperature (centigrade), the pressure (in millimeters of mercury),† and the density calculated from the temperature and pressure by equation (10). The subsequent columns give the densities observed by different authorities, and the excess of the observed over the calculated densities. In the first column of observed densities, we have one observation by Mitscherlich‡ (at 100·25°) and five by R. Müller.§ The three remaining columns contain each the results of a series of experiments by Deville and Troost.‖ In each series the experiments were made with increasing temperatures, and with the same vessel, without refilling. It should be observed that the results of the three series are not regarded by their distinguished authors as of equal weight. It is expressly stated that the numbers in the two earlier series, and especially in the first, may be less exact. The last series agrees very closely with the formula. It was from this that the constants of the formula were determined. The experiments of series I and II, and those of Mitscherlich and Müller, give somewhat larger values, with a single exception, as is best seen in the columns which give the excess of the observed density. The differences between the different columns are far too regular to be attributed to the accidental errors of the individual observations, except in the case of the experiment at 151·8°,

* See equation (336) on page 339, *loc. cit.*,—also the following equations in which the density is given in terms of the temperature and pressure. In comparing these equations, it must be observed that in (336) the pressures are measured in atmospheres, but in this paper in millimeters of mercury.

† 760mm has been assumed as the pressure of the atmosphere in all cases in which the precise pressure is not recorded in the published account of the experiments. The figures inserted in the columns of pressures are in such cases enclosed in parentheses. The same course has been followed in the subsequent tables. With respect to the principal series of observations by Deville and Troost (series III), it is stated that the barometer varied between 747 and 764 millimeters. A difference of 13 millimeters in the pressure would in no case cause a difference of ·005 in the calculated densities. In this series, therefore, the errors due to this circumstance are not very serious.

‡ Pogg. Ann., vol. xxix (1833), p. 220.

§ Lieb. Ann., vol. cxxii (1862), p. 15.

‖ Comptes Rendus, vol. lxiv (1867), p. 237.

where some accident has evidently occurred either in the experiment itself or in the reduction of the result. Setting this observation aside, we must look for some constant cause for the other discrepancies between the different series.

We can hardly attribute these discrepancies to difference in the material employed, or to air or other foreign substance imperfectly expelled from the flask. For impurities which increase the density would make the divergence between the different series greatest when the densities are the least, whereas the divergences seem to vanish as the density approaches the limiting value. (A similar objection would apply to the supposition of any error in the determination of the weight of the flask when filled with air alone.) But if we should attribute the divergences to an impurity which diminishes the density (as air), we should be driven to the conclusion that the first series of Deville and Troost gives the most correct results, and that all the best attested numbers at temperatures below 90° are considerably in the wrong. It does not seem possible to account for these discrepancies by any causes which would apply to cases of normal or constant density. They are illustrations of the general fact that when the density varies rapidly with the temperature, determinations of density for the same temperature and pressure by different observers, or different determinations by the same observer, exhibit discordances which are entirely of a different order of magnitude from those which occur with substances of normal or constant densities, or which occur with the same substance at temperatures at which the density approaches a constant value. In some cases such results may be accounted for by carelessness on the part of the observers, not controlled by a comparison of the result with a value already known. But such an explanation is inadequate to explain the general fact, and evidently inadmissible in the present case.

It is probable that these discrepancies are in part attributable to a circumstance which has been noticed by M. Wurtz, in his account of his experiments upon the vapor-density of bromhydrate of amylene, in the following words: "Le temps pendant lequel la vapeur est maintenue à la température où l'on détermine la densité n'est pas sans influence sur les nombres obtenus. C'est ce qui résult des deux expériences faites à 225 degrés avec des produits identiques. Dans la première, la vapeur a été portée rapidement à 225 degrés. Dans la seconde elle a été maintenue pendant dix minutes à cette température. On voit que les nombres trouvés pour les densités ont été fort différents. [The numbers were 4·69 and 3·68 respectively.] Ce résultat ne doit point surprendre si l'on considère que le phénomène de décomposition de la vapeur doit absorber de la chaleur, et que les quantités de chaleur nécessaires pour pro-

duire et la dilatation et la décomposition ne sauraient être fournies instantanément."*

It is not difficult to form an estimate of the quantities of heat which come into play in such cases. With respect to peroxide of nitrogen, it was estimated in the paper already cited that the heat absorbed in the conversion of a unit of N_2O_4 into NO_2 under constant pressure is represented by 7181 a_2. (The heat is supposed to be measured in units of mechanical work). Now the external work done by the conversion of a unit of N_2O_4 into NO_2 under constant pressure is a_2t. Therefore, the ratio of the heat absorbed to the external work done by the conversion of N_2O_4 into NO_2 is $7181 \div t$, or 23 at the temperature of 40° centigrade. Let us next consider how much more rapidly this vapor expands with increase of temperature at constant pressure than air. From the necessary relation

$$v = \frac{kmt}{p\mathrm{D}},$$

where m denotes the weight of the vapor, and k a constant, we obtain

$$\left(\frac{dv}{dt}\right)_p = \frac{v}{t} - \frac{v}{\mathrm{D}}\left(\frac{d\mathrm{D}}{dt}\right)_p,$$

where the suffix $_p$ indicates that the differential coefficients are for constant pressure. The last term of this expression evidently denotes the part of the expansion which is due to the conversion of N_2O_4 into NO_2, and the preceding term the expansion which would take place if there were no such conversion, and which is identical with the expansion of the same volume of air under the same circumstances. The ratio of the two terms is $-\frac{t}{\mathrm{D}}\left(\frac{d\mathrm{D}}{dt}\right)_p$, the numerical value of which for the temperature of 40° is 2·42, as may be found by differentiating equation (10), or, with less precision, from the numbers in the third column of Table I. Let us now suppose that equal volumes of peroxide of nitrogen and of air at the temperature of 40° and the pressure of one atmosphere receive equal infinitesimal increments of temperature under constant pressure. The heat absorbed by the peroxide of nitrogen on account of the conversion of N_2O_4 into NO_2 is 23 times the external work due to the same cause, and this work is 2·42 times the external work done by the expansion of the air. But the heat absorbed by the air in expanding under constant pressure is well known to be 3·5 times the work done. Therefore the heat absorbed on account of the conversion of N_2O_4 into NO_2 is $(23 \times 2{\cdot}42 \div 3{\cdot}5 =)15{\cdot}9$ times the heat absorbed by the air. To obtain the

* Comptes Rendus, t. lx, p. 730.

whole heat absorbed by the vapor we must add that which would be required if no conversion took place. At 40° the vapor of peroxide of nitrogen contains about 54 molecules of N_2O_4 to 46 of NO_2, as may easily be calculated from its density. The specific heat for constant pressure of a mixture in such proportions of gases of such molecular formulæ, if no chemical action could take place, would be about twice that of the same volume of air. Adding this to the heat absorbed by the chemical action we obtain the final result,—that at 40° and the pressure of the atmosphere the specific heat of peroxide of nitrogen at constant pressure is about eighteen times that of the same volume of air.*

But the greater amount of heat which is required to bring the vapor to the desired temperature is only one factor in the increased liability to error in cases of this kind. The expansion of peroxide of nitrogen for increase of temperature under constant pressure at 40° is 3·42 times that of air. If then, in a determination of density, the vapor fails to reach the temperature of the bath, the error due to the difference of the temperature of the vapor and the bath, will be 3·42 times as great as would be caused by the same difference of temperatures in the case of any vapor or gas having a constant density. When we consider that we are liable not only to the same, but to a much greater difference of temperatures in a case like that of peroxide of nitrogen, when the exposure to the heat is of the same duration, it is evident that the common test of the exactness of a process for the determination of vapor-densities, by applying it to a case in which the density is nearly constant, is entirely insufficient.

That the experiments of the III[d] series of Deville and Troost give numbers so regular and so much lower than the other experiments is probably to be attributed in part to the length of time of exposure to the heat of the experiment, which was half an hour in this series,—for the other series, the time is not given.

Another point should be considered in this connection. During the heating of the vapor in the bath, it is not immaterial whether the flask is open or closed. This will appear, if we compare the values of $\left(\frac{d\mathrm{D}}{dt}\right)_p$ and $\left(\frac{d\mathrm{D}}{dt}\right)_v$, the differential coefficients of the density with respect to the temperature on the suppositions, respectively, of constant pressure, and of constant volume. For 40°, we have

$$\left(\frac{d\mathrm{D}}{dt}\right)_p = \cdot 0189, \qquad \left(\frac{d\mathrm{D}}{dt}\right)_v = \cdot 0163,$$

* Similar calculations from less precise data for the bromhydrate of amylene at 225° seem to indicate a specific heat as much as forty times as great as that of the same volume of air.

the first number being obtained immediately from equation (10) by differentiation, and the second by differentiation after substitution of $\frac{kmt}{vD}$ for p. The ratio of these numbers evidently gives the proportion in which the chemical change takes place under the two suppositions. This shows that only about six-sevenths of the heat required for the chemical change can be supplied before opening the flask, and the remainder of this heat as well as that required for expansion must be supplied after the opening. The errors due to this source may evidently be diminished by diminishing the intervals of temperature between the successive experiments in a series of this kind, and also by diminishing the opening made in the flask, which increases the time for which the flask may be left open without danger of the entrance of air. In the III^d series of experiments by Deville and Troost, the intervals of temperature did not exceed ten degrees (except after the density had nearly reached its limiting value), and the neck of the flask was drawn out into a very fine tube.

In Table II, which relates to experiments on the same substance at pressures less than that of the atmosphere, the principal series is that of Naumann,* which commences a few degrees below the lowest temperatures of Deville and Troost, and extends to $-6°$ centigrade, the pressures varying from 301 to 84 millimeters. These experiments were made by the method of Gay-Lussac. The numbers in the column of observed densities have been re-calculated from the more immediate results of the experiments, and are not in all cases identical with those given in Professor Naumann's paper. Every case of difference is marked with brackets. Instead of the numbers [2·66], [2·62], [2·85], [2·94], Naumann's paper has 2·57, 2·65, 2·84, 3·01, respectively. In some cases the temperatures and pressures of two experiments are so nearly the same that it would be allowable to average the results, at least in the column of excess of observed density. In such cases the numbers in this column have been united by a brace. The greatest difference between the observed and calculated densities is ·16, which occurs at the least pressure, 84 millimeters. In this experiment the weight of the substance employed is also less than in any other experiment. Under such circumstances, the liability to error is of course greatly increased. The average difference between the observed and calculated densities is ·063. Since these differences are almost uniformly positive and increase as the temperature diminishes, it is evident that they might be considerably diminished by slight changes in the constants of equation (10), without seriously impairing the agreement of that equa-

* Berichte der Deutschen Chemischen Gesellschaft, Jahrgang xi (1878), S. 2045.

tion with the experiments of Deville and Troost. But it has not seemed necessary to re-calculate the formula, which, in its present form, will at least illustrate the degree of accuracy with which densities at low pressures and at temperatures below the boiling point of the liquid may be derived from experiments at atmospheric pressure above the boiling point. Moreover, the excess of observed density may be due in part to a circumstance mentioned by Professor Naumann, that the chemical action between the vapor and the mercury diminished the volume of the vapor, and thus increased the numbers obtained for the density.

Table II.—Peroxide of Nitrogen.

Experiments at less than Atmospheric Pressure.

Playfair and Wanklyn,—Troost,—Naumann.

Temperature.	Pressure.	Density calculated by eq. (10).	Density observed.			Excess of obs. density.		
			P. & W.	T.	N.	P. & W.	T.	N.
97·5	(301)	1·631	1·783			+·152		
27	35	1·90		1·6			—·30	
27	16	1·77		1·59			—·18	
24·5	(323)	2·524	2·52			—·004		
22·5	136·5	2·34			2·35			+·01
22·5	101	2·26			2·28			+·02
21·5	161	2·41			2·38			—·03
20·8	153·5	2·41			2·46			+·05
20	301	2·59			2·70			+·11
18·5	136	2·43			2·45			+·02
18	279	2·61			2·71			+·10
17·5	172	2·51			2·52			+·01
16·8	172	2·53			2·55			+·02
16·5	224	2·59			[2·66]			+·07
16	228·5	2·61			[2·62]			+·01
14·5	175	2·58			2·63			+·05
11·3	(159)	2·620	2·645			+·025		
11	190	2·66			2·76			+·10
10·5	163	2·64			2·73			+·09
4·2	(129)	2·710	2·588			—·122		
4	172·5	2·77			2·85			+·08
2·5	145	2·76			[2·85]			+·09
1	138	2·78			2·84			+·06
—1	153	2·83			2·87			+·04
—3	84	2·76			2·92			+·16
—5	123	2·85			2·98			+·13
—6	125·5	2·87			[2·94]			+·07

The same table includes two experiments of Troost,* by Dumas' method, but at the very low pressures of 35^{mm} and 16^{mm}. In such experiments we cannot expect a close agreement with the formula, for the same error in the determination of the weight of the vapor, which would make a difference of

* Comptes Rendus, t. lxxxvi (1878), p. 1395.

·01 in the density in experiments at atmospheric pressure, would make a difference of ·21 or ·47 in the circumstances of these experiments. In fact, the numbers obtained differ considerably from those demanded by the formula.

There remain four experiments by Playfair and Wanklyn* in which Dumas' method was varied by diluting the vapor with nitrogen. The numbers in the column of pressures represent the total pressure diminished by the pressure which the nitrogen alone would have exerted. They are not quite accurate, since the data given to the memoir cited only enable us to determine the ratios of the total and the partial pressures. The numbers here given are obtained by setting the total pressure, which was that of the atmosphere at the time of the experiment, equal to 760^{mm}. The effect of this inaccuracy upon the calculated densities would be small. Two of these observations agree closely with the formula; and two show considerable divergence, but in opposite directions, and these are the two in which the quantities of peroxide of nitrogen were the smallest. The differences appear to be attributable rather to the difficulty of a precise determination of the quantities of nitrogen and of vapor, than to any effect of the one upon the other.

Special interest attaches to experiments at the same or nearly the same temperature but different pressures. For with experiments at the same temperature, the constants of the formula which are determined by observation are reduced to one, so that the verification of the formula by experiment cannot possibly be regarded as a case of interpolation. It is not necessary that the temperatures should be exactly the same, for it will be conceded that the formula represents the actual function well enough to answer for adjusting slight differences of temperature; but it is necessary that the range of pressures should be considerable in order that the differences of density should be large in proportion to the probable errors of observation. But the pressures must not be so low that accurate determinations become impossible.

In the experiments of Naumann we see some fair correspondences with the formula in respect to the influence of pressure, especially in the first four experiments of the list, where, if we average the results of the third and fourth experiments, as is evidently allowable, the observed values follow very closely the fluctuations of the calculated, extending from 2·26 to 2·41. In other cases the agreement is less satisfactory. The circumstance that the experiments at the two highest pressures (301 and 279^{mm}), give results exceeding the calculated values considerably more than any other experiments at adjacent temperatures may seem to indicate that the densities

* Trans. Roy. Soc. Edinb., vol. xxii (1861), p. 463.

increase with the pressures more rapidly than the formula allows; but the differences are not too large to be ascribed to errors of observation, and the experiment at the lowest pressure (84^{mm}) also shows a large excess of observed density.

A much more critical test may be found in the comparison of Naumann's experiments with those of Deville and Troost, notwithstanding the interval of about 4° of temperature. The formula requires that a diminution of pressure from 760 to 101 millimeters shall reduce the density from 2·676 at 26·7° to 2·26 at 22·5, notwithstanding the effect of the change of temperature. Experiment gives a reduction of density from 2·65 to 2·28, which is about one-ninth less. This is, it will be observed, a deviation from the formula in the opposite direction from that which the experiments of Naumann alone, or a comparison of the experiments of Troost with those of Deville and Troost, seemed to indicate. The experiment here compared with Naumann's belongs to the IIId series of Deville and Troost. If instead of this experiment we should take an average of the experiments at lowest temperature in the IId and IIId series, the agreement with the formula with respect to the effect of change of pressure would be almost perfect.

Formic acid.—In Table III, the determinations of Bineau are compared with the densities calculated by the formula

$$\log\frac{1{\cdot}589\,(D-1{\cdot}589)}{(3{\cdot}178-D)^2}=\frac{3800}{t_c+273}+\log p-12{\cdot}641. \qquad (11)$$

The observed densities are taken from the eighteenth volume of the third series of the Annales de Chimie et de Physique (1846), except in three cases, distinguished by parentheses, which are earlier determinations published in the nineteenth volume of the Comptes Rendus (1844). It may be added that the pressure (687) for the experiment at 108° is taken from Erdmann's Journal für praktische Chemie (vol. xl, p. 44), the impression being imperfect in the Annales, in the copies to which the writer has been able to refer, where the figures look much like 637. (The pressure 637 would make the calculated density 2·28.)

In the column which gives the excess of observed densities, the effect of nearness to the state of saturation is often very marked. Such cases are distinguished by an asterisk. The temperature of 99·5° is below the boiling point of formic acid, and the higher pressures employed at this temperature cannot be far from the pressure of saturated vapor. With respect to lower temperatures, we have the statement of Bineau that the pressure of saturated vapor is about 19^{mm} at 13°, $20{\cdot}5^{mm}$ at 15°, $33{\cdot}5^{mm}$ at 22°, and $53{\cdot}5^{mm}$ at 32°. By interpolation between the *logarithms* of these pressures, (in a single case, by *extrapolation*), we obtain the following result.

Temperature	10·5	12·5	16	18·5	22
Pressure of sat. vapor	16·6	18·5	22	26·2	33·5
Pressure of experiment	14·69	15·20	15·97	23·53	25·17

TABLE III.—FORMIC ACID.

Experiments of BINEAU.

Temperature.	Pressure.	Density calculated by eq. (11).	Density observed.	Excess of observed density.
216·0	690	1·60	1·61	+·01
184·0	750	1·64	1·68	+·04
125·5	687	2·03	2·05	+·02
125·5	645	2·02	2·03	+·01
124·5	670	2·04	2·06	+·02
124·5	640	2·03	2·04	+·01
118·0	655	2·13	(2·14)	(+·01)
118·0	650	2·13	2·13	·00
117·5	688	2·15	2·13	—·02
115·5	649	2·17	2·20	+·03
115·5	640	2·16	2·16	·00
115	655	2·18	(2·13)	(—·05)
111·5	690	2·25	2·22	—·03
111·5	690	2·25	2·25	·00
111	608	2·22	(2·13)	(—·09)
108	[687]	2·30	2·31	+·01
105·0	691	2·35	2·35	·00
105·0	650	2·34	2·33	—·01
105·0	630	2·33	2·32	—·01
101·0	693	2·42	2·44	+·02
101·0	650	2·40	2·41	+·01
99·5	690	2·44	2·52	+·08*
99·5	684	2·44	2·49	+·05
99·5	676	2·44	2·46	+·02
99·5	662	2·43	2·44	+·01
99·5	641	2·42	2·42	·00
99·5	619	2·41	2·41	·00
99·5	602	2·41	2·40	—·01
99·5	557	2·39	2·34	—·05
34·5	28·94	2·82	2·77	—·05
31·5	3·04	2·40	2·60	+·20
30·5	8·83	2·67	2·69	+·02
30·0	18·28	2·81	2·76	—·05
29·0	27·40	2·88	2·83	—·05
24·5	17·39	2·88	2·86	—·02
22·0	25·17	2·95	3·05	+·10*
20·0	16·67	2·93	2·94	+·01
20·0	7·99	2·84	2·85	+·01
20·0	2·72	2·64	2·80	+·16
18·5	23·53	2·98	3·23	+·25*
16·0	15·97	2·97	3·13	+·16*
15·5	2·61	2·72	2·86	+·14
15·0	7·60	2·90	2·93	+·03
12·5	15·20	3·00	3·14	+·14*
11·0	7·26	2·95	3·02	+·07
10·5	14·69	3·01	3·23	+·22*

Whether the large excess of observed density in these case represents a property of the vapor, or an incipient condensation

on the walls of the vessel which contains it, as has been supposed by eminent physicists in similar cases, we need not here discuss.

If we reject these cases of nearly saturated vapor, as well as the three earlier determinations, there remain 25 experiments at pressures somewhat less than one atmosphere in which the maximum difference between the observed and calculated densities is ·05, and the average difference ·016; nine experiments at pressures ranging from 29^{mm} to 7^{mm}, in which the maximum difference is ·07 and the average ·035; and three experiments at pressures of about 3^{mm}, in which the average difference is ·17. The extraordinary precision of the determinations at low pressures is doubtless due to the large scale on which the experiments were conducted. All the experiments at temperatures below 99°, were made with a globe of the capacity of 5½ liters with a stem of suitable length to hold the barometric column.

The agreement is certainly as good as could be desired, and shows the accuracy of which the method of observation is capable. But in no part of the thermometric scale do we find so great a range of pressures as might be desired, without using pressures too low for accurate results, or observations which are to be rejected for other reasons.

[To be continued.]

ART. XXXVIII.—*The Fault at Rondout*; by T. NELSON DALE, Jr.

MATHER gives a section,* from between Glasco and Great Falls of Esopus Creek, in which the Hudson River slates and the Lower Helderberg limestones are unconformably superposed, and the latter present the form of a ruptured and eroded anticlinal. He gives also, Plate 8, fig. 7, a rough and unsatisfactory section of "High Rock," situated opposite Rhinebeck, between the junction of the Wallkill and the Hudson. In this section the Lower Helderberg limestones are represented in an almost erect position, resting unconformably upon Hudson River grits.

Mr. J. G. Lindsley, the agent of the Cement Co. at Rondout, read an interesting paper† before the Poughkeepsie Society of Natural Science on Feb. 26, 1879, which contains the results of local studies for which he has had excellent opportunities.

In the summer of 1878, I made several hasty visits to the highly instructive locality at Rondout, and obtained the following data, some of which, as well as the inferences from them, are not given in Mr. Lindsley's paper. The southeast base of

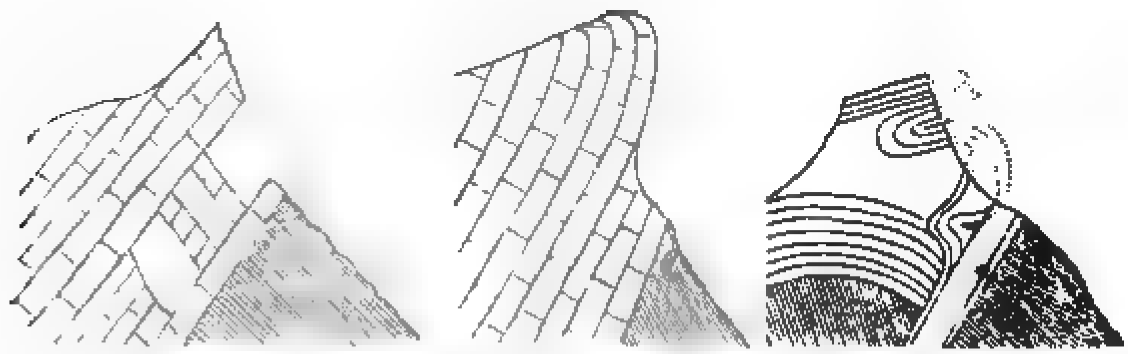
* Nat. Hist. of N. Y., Part IV, Geology, by W. W. Mather. Pl. 7, fig. 9, 1843.

† "A Study of the Rocks," by James G. Lindsley, in the forthcoming Part I, vol. ii, of Proceedings of the Poughkeepsie Society of Natural Science.

the hill consists of grit dipping east-northeast at an angle of about 45°. These grits form part of the series of clay-slates and grits of the Hudson River group.* Unconformably resting upon these grits is a series of limestones, dipping at about the same angle, but toward the northwest. The grits are non-fossiliferous at this point. The limestones are abundantly fossiliferous. I am indebted to Mr. Lindsley for the following measurements of the latter.

Beginning above: No. 9, 20 feet or more, Upper Pentamerus limestone. No. 8, 20 feet, Encrinal limestone. No. 7, 15–20 feet, Delthyris limestone. No. 6, 20 feet Lower Pentamerus limestone with chert, *Pentamerus galeatus*, Crinoids. No. 5, 6 feet, Ribbon limestone with *Stromatopora concentrica*. No. 4, 15 feet, Tentaculite limestone with *Tentaculites irregularis*, *Leperditia alta*. No. 3, 4 feet, limestone with prismatic mud cracks. No. 2, 30 feet, Water-lime with *Leperditia alta*. No. 1, 6 feet, Encrinal limestone. Whatever may be thought as to the presence in No. 1 and 2 of Niagara beds, we certainly have to do with Lower Helderberg in part of No. 2 and in No. 3 and 4. The relative position of the rocks is shown in the accompanying sections. For Section No. 3, I am indebted to Mr. Lindsley. The excavations represented in figure 1 were made in quarrying, the rock being a hydraulic limestone or "cement rock."

1. 2. 3.



Figs. 1 to 3. Lower Helderberg beds resting unconformably on the Hudson River group (fine-lined portion in the figures); in figs. 1 and 2, dip of L. H. northwest, of H. R. east-northeast.

It has been supposed, I believe by Sir William Logan, that the great fault which begins near Quebec, crosses the Hudson near Rhinebeck, and there separates the Quebec from the true Hudson River beds.† It would appear that this is erroneous and that the facts of the case at these localities are simply these. At the close of the Hudson River Period, the Lower Silurian beds were powerfully folded and metamorphosed. A period of uplift and erosion followed; then a depression and the deposition

*See this Journal, III, vol. xvii, 1879, page 57. "On the Age of the Clay-slates and Grits of Poughkeepsie" by T. Nelson Dale, Jr.

† Dana, Manual of Geology, page 184, 2d edition, 1876.

of the Upper Silurian series. At some later time, probably at the period of the Appalachian revolution, the whole series, i. e. the Hudson River and Lower Helderberg formations, were uplifted, folded, fractured, faulted and tilted.

The complicated stratification of Section 3, may perhaps be accounted for as follows. First, unconformable deposition of Lower Helderberg upon Hudson River beds; then the formation of an anticlinal, and at the same time, closely adjoining it, a treble fold. The folds by the continued pressure were broken off from the anticlinal and thrown into an erect position. The same force has also compressed the lowest fold between the edges of the anticlinal on one side, and the surface of other Lower Helderberg strata on the other. The uppermost layers of this fold were by this action ruptured. This is not shown in the cut. As the upper portion of the base of the hill has been quarried away, the segments of three folds are now in view, one above another. The thickness of the contorted strata has been much reduced by pressure.

ART. XXXIX.—*On the Chemical Composition of Amblygonite;* by SAMUEL L. PENFIELD.

THE new mineral species triploidite described by Messrs. Brush and Dana* is shown by them to be isomorphous with wagnerite and closely related in composition to triplite. These three minerals have respectively the formulas $(Mn,Fe)_3 P_2O_8+(Mn,Fe)(OH)_2$, $Mg_3 P_2O_8+MgF_2$ and $(Fe,Mn)_3 P_2O_8+(Fe,Mn)F_2$. From a comparison of these formulas it is argued (l. c., p. 45) that the relation between the minerals requires the assumption that the hydroxyl in triploidite must play the same part as the fluorine in the other two.

In this paper I wish to show that in amblygonite the hydroxyl group is also isomorphous with fluorine, and that in chemical composition the original amblygonite does not differ from the American and Montebras varieties which have been called hebronite. I shall also show that the results of my analyses require the adoption of a new formula for the mineral, more simple than that previously accepted. For analysis I have selected specimens from the three localities in Maine, from Branchville, Connecticut, where the mineral has been lately discovered by Messrs. Brush and Dana, also two varieties from Montebras and one from Penig, Saxony, from a specimen in the Yale College collection.

The analyses are arranged so as to form a series, beginning with the one which contains the smallest amount of water.

* This Journal, III, xvi, 42, July, 1878.

I. *Penig, Saxony.*

	I.	II.	Mean.	Relative number of atoms.			
P_2O_5	48·35	48·13	48·24	P	·678		1·
Al_2O_3	33·50	33·60	33·55	Al	·651		·96
Li_2O	8·97	8·97	8·97	Li	·598	·664	·98
Na_2O	2·06	2·03	2·04	Na	·066		
Mn_2O_3	·12	·15	·13				
H_2O	1·75		1·75	OH	·194	·786	1·16
F	11·26		11·26	F	·592		
			105·94				
O equivalent of F			4·74				
			101·20				

II. *Montebras, France, variety A.* G.=3·088.

	I.	II.	Mean.	Relative number of atoms.			
P_2O_5	47·10	47·07	47·09	P	·664		1·
Al_2O_3	33·20	33·25	33·22	Al	·646		·97
Li_2O	7·93	7·90	7·92	Li	·528	·649	·98
Na_2O	3·48	....	3·48	Na	·112		
CaO	·25	·24	·24	Ca	·009		
H_2O	2·25	2·29	2·27	OH	·252	·775	1·17
F	10·00	9·86	9·93	F	·523		
			104·15				
O equivalent of F			4·02				
			100·13				

III. *Auburn, Maine.* G.=3·059.

	I.	II.	Mean.	Relative number of atoms.			
P_2O_5	48·56	48·40	48·48	P	·683		1·
Al_2O_3	33·67	33·90	33·78	Al	·656		·96
Li_2O	9·49	9·42	9·46	Li	·630	·662	·97
Na_2O	·96	1·02	·99	Na	·032		
H_2O	3·61	3·52	3·57	OH	·396	·722	1·06
F	6·26	6·15	6·20	F	·326		
			102·48				
O equivalent of F			2·61				
			99·87				

IV. *Hebron, Maine, variety A.*

		Relative number of atoms.			
P_2O_5	By difference [48·53]	P	·682		1·
Al_2O_3	34·12	Al	·662		·97
Li_2O	9·54	Li	·636	·646	·95
Na_2O	·34	Na	·010		
H_2O	4·44	OH	·493	·769	1·13
F	5·24	F	·276		

This sample was accidentally lost before a phosphoric acid determination was made. It is inserted because it is regarded as a good analysis and it varies somewhat from the other sample from Hebron which was obtained to replace it.

V. *Paris, Maine.* G.=3·035.

	I.	II.	Mean.	Relative number of atoms.			
P_2O_5	48·28	48·35	48·31	P	·680		1·
Al_2O_3	33·87	33·50	33·68	Al	·654		·96
Li_2O	9·83	9·80	9·82	Li	·654	·664	·97
Na_2O	·43	·24	·34	Na	·010		
K_2O	·03	...	·03				
H_2O	4·96	4·82	4·89	OH	·543	·797	1·17
F	4·82	4·82	4·82	F	·254		
			101·89				
O equivalent of F			2·03				
			99·86				

VI. *Hebron, Maine, variety B.* G.=3·032.

	I.	II.	Mean.	Relative number of atoms.			
P_2O_5	47·44	47·44	47·44	P	·668		1·
Al_2O_3	33·79	34·01	33·90	Al	·658		·98
Li_2O	....	9·24	9·24	Li	·616	·638	·95
Na_2O	....	·66	·66	Na	·022		
H_2O	5·00	5·10	5·05	OH	·561	·848	1·27
F	5·53	5·36	5·45	F	·287		
			101·74				
O equivalent of F			2·29				
			99·45				

VII. *Branchville, Connecticut.* G.=3·032.

	I.	II.	Mean.	Relative number of atoms.			
P_2O_5	48·80	48·81	48·80	P	·686		1·
Al_2O_3		34·26	34·26	Al	·665		·97
Li_2O	9·69	9·90	9·80	Li	·653	·659	·96
Na_2O	·15	·24	·19	Na	·006		
Fe_2O_3	·29	·29	·29				
Mn_2O_3	·10	·10	·10				
H_2O	5·93	5·90	5·91	OH	·658	·750	1·09
F	1·75	1·75	1·75	F	·092		
			101·10				
O equivalent of F			·74				
			100·36				

VIII. *Montebras, France, variety B.* G.=3·007.

	I.	II.	Mean.	Relative number of atoms.			
P_2O_5	48·31	48·38	48·34	P	·681		1·
Al_2O_3	33·73	33·38	33·55	Al	·651		·96
Li_2O	9·53	9·50	9·52	Li	·634		
Na_2O	·34	·33	·33	Na	·010	·654	·96
CaO	·40	·30	·35	Ca	·010		
H_2O	6·61	6·61	6·61	OH	·734	·826	1·21
F	1·76	1·74	1·75	F	·092		
			100·45				
O equivalent of F			·74				
			99·71				

For more easy comparison the ratios from the above analyses are collected in the following table by themselves, where $\overset{\text{I}}{R}$ equals Li and Na.

		P	Al	$\overset{\text{I}}{R}$	(OH, F)
I.	Penig, Saxony	1·00	·96	·98	1·16
II.	Montebras, France, A	1·00	·97	·98	1·17
III.	Auburn, Maine	1·00	·96	·97	1·06
IV.	Hebron, Maine, A	1·00	·97	·95	1·13
V.	Paris, Maine	1·00	·96	·97	1·17
VI.	Hebron, Maine, B	1·00	·98	·95	1·27
VII.	Branchville, Conn.	1·00	·97	·96	1·09
VIII.	Montebras, France, B	1·00	·96	·96	1·21

It will be seen that all of these approach closely to the ratio 1 : 1 : 1 : 1, hence I propose the formula $Al_2P_2O_8+2R(OH, F)$ or $\left.\begin{matrix}3Al_2P_2O_8\\2R_3PO_4\end{matrix}\right\} + \left\{\begin{matrix}Al_2(OH, F)_6\\2R(OH, F)\end{matrix}\right.$ as the true formula for all varieties of this mineral.

DesCloizeaux, from a difference in optical characters made out by him, has divided the mineral into two species: the original amblygonite, including I and II in the above list; and a second species for which he proposed the name *montebrasite* (hebronite of von Kobell), including analyses III to VIII above. The mineral from Branchville has not been examined optically and the material is very unfavorable for such an examination. Owing to the close identity in chemical composition it seems that a slight variation in optical properties is hardly sufficient ground for dividing the mineral into two species, but on the contrary I think that the old name amblygonite should be retained, and that all varieties should be included by it.

It will be seen in comparing the above ratios that in every case the ratio of P to (OH, F) is in excess of that of the Al to R. Two theories suggest themselves to account for this, the first of which seems the most plausible. First: most minerals which are ordinarily regarded as anhydrous contain a small amount of water, which is not calculated in the ratios, and which is not regarded as essential to the composition. Now if these minerals contain a small quantity of such accidental water, it will bring up the ratios very considerably, owing to the small molecular weight of water, and if the slight variation between P, Al and R be regarded as due to error of analysis the excess of (OH, F) would be easily accounted for. Second: if we regard the difference between P, Al and R as not due to error of analysis, and the fact that the variation in all is so constant suggests this, and regard enough of the water basic so that when added to the Al and R it will make the ratio with P equal 1 : 1 : 1, then the ratio of (OH, F) will be: Penig, 1·02;

Montebras, A, 1·06: Auburn, 0·91; Hebron, A, 0·99; Paris, 1·02; Hebron, B, 1·18; Branchville, 0·97; Montebras, B, 1·05. This relation seems rather striking, and although it is not as simple as we should like to have it, or perhaps as plausible as the first theory, yet it may possibly be the correct one. Whichever of these explanations is accepted, it will not materially alter the formula above made out for the minerals, the variation from which is too slight and not constant enough to be expressed by any different formula. It will be seen from analyses I and II that water is found in the Penig and Montebras varieties which have been regarded as anhydrous by some analysts. This may have been overlooked, and it is worth noting that in Plattner's Blowpipe Analysis the statement is made, of the Penig mineral, that water is expelled by heating in a closed tube. It will also be seen that these analyses differ from the older ones in that they are lower in alumina and higher in alkalies. I have thought it best to give my method of analysis in full, which may account for some of the variations.

Method of Analysis.

Water was determined by ignition with oxide of lead in a porcelain crucible; it is completely driven off only by strong ignition, and it was found necessary to fuse the contents of the crucible over the blast lamp before constant results could be obtained. Fluorine was determined by decomposing a mixture of the mineral and powdered quartz with sulphuric acid, converting the silicon fluoride formed into hydrofluosilicic acid, precipitating the hydrofluosilicic acid with potassium chloride and titrating the liberated hydrochloric acid with a standard alkali solution.* The varieties from Penig and Montebras are decomposed only by prolonged action of sulphuric acid. Phosphoric acid was determined by fusing the mineral with sodium carbonate, boiling out the fused mass with water and dilute nitric acid, nearly neutralizing the excess of acid with ammonia, precipitating with molybdic solution and then proceeding in the usual way.

To determine the bases, one gram was weighed into a large platinum crucible, mixed into a paste with from two to three cubic centimeters of sulphuric acid, and heated, with the crucible covered, over a low gas flame till not over a cubic centimeter of sulphuric acid remained. The contents of the crucible were then rinsed into a platinum evaporating dish and treated with a quantity of strong hydrochloric acid; after heating and concentrating a clear solution was obtained. The excess of acid being removed by evaporation, the contents of the dish were rinsed into a beaker, filtered where necessary, the

* See Remsen's American Chemical Journal, vol. i, No. 1.

undissolved portion after incinerating the filter paper was treated with hydrofluoric acid, then with a drop of sulphuric acid; the hydrofluoric acid expelled by evaporation and the solution added to the other solution of the bases. To obtain the bases as chlorides the sulphuric acid was precipitated from the solution with barium chloride, and the barium sulphate filtered off. The solution was then heated to boiling and a hot solution of barium hydroxide added; this precipitated all the phosphoric acid and part of the alumina. The solution contained all the lithia and most of the alumina which went into solution in the excess of barium hydroxide. After filtering and washing the precipitate it was dissolved in hydrochloric acid, the excess expelled by evaporation; the residue taken up in a few drops of hydrochloric acid and water and poured when hot into a boiling solution of sodium hydroxide and a little barium hydroxide in a platinum dish; this again precipitated all the phosphoric acid while the alumina went into solution in the alkaline hydroxides. After filtering, the filtrate was acidified with hydrochloric acid, the barium precipitated with sulphuric acid, and the alumina precipitated with ammonia. The alumina found at this point amounted usually to about one-half per cent. The insoluble barium phosphate containing also traces of iron, manganese, and calcium was dissolved in hydrochloric acid, the barium precipitated with sulphuric acid, filtered and the filtrate made alkaline with ammonia; this precipitated any iron, manganese or calcium as phosphate which was filtered off and examined separately. It was intended at this point to determine the phosphoric acid by direct precipitation with magnesia mixture, but the results coming out too low an examination of all the barium sulphate precipitates showed that a quantity of the phosphoric acid had been precipitated along with the barium sulphate. The first filtrate from the barium hydroxide precipitate contained, free from phosphoric acid, all the lithia, the larger part of the alumina, and the excess of barium. It was heated to boiling and ammonium carbonate added; this precipitated the barium and aluminium and left the lithia in solution. The precipitate was washed first by decantation, then with hot water on the filter pump; it was not considered free from lithia, however, as it is practically impossible to wash a large barium carbonate precipitate free from lithia. The filtrate was evaporated to dryness, the ammonia salts expelled by ignition, traces of barium separated a second or third time when necessary, evaporated to dryness again, lithia separated from soda and potash by means of absolute alcohol and ether, the lithia weighed as sulphate and the soda and potash as chlorides. The chlorides were tested carefully for potash by evaporating with excess of platinum

chloride and taking up in alcohol. The precipitate produced by ammonium carbonate was dissolved in hydrochloric acid, the barium precipitated with sulphuric acid, filtered and alumina precipitated in the filtrate with ammonia, the precipitate was washed with hot water, ignited finally over the blast lamp to expel sulphuric acid and weighed as oxide. The filtrate from the alumina was regarded as containing a trace of lithia which had been retained by the barium carbonate precipitate, it was evaporated to dryness, the ammonia salts expelled by ignition, taken up in water, filtered into a weighed crucible, evaporated to dryness and weighed, the lithia found amounted to from one-quarter to one per cent.

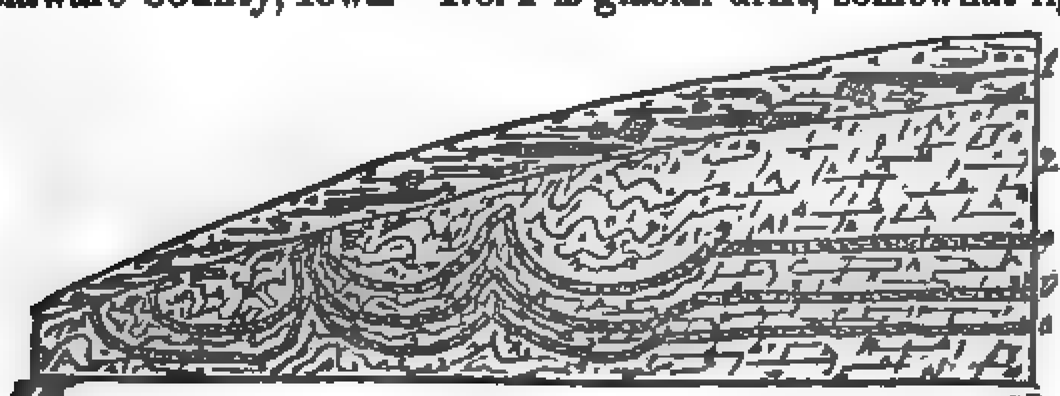
The solutions were kept as far as possible from all contact with glass, the evaporations being carried on in large platinum dishes. The reagents were carefully selected and purified. Sodium hydroxide free from aluminium and silica was obtained, prepared from metallic sodium. Owing to the limited amount of material from Penig only three-quarters of a gram was used in the determinations, and duplicates of the water and fluorine determination were not obtained. For the occurrence and associations of amblygonite at Branchville, Connecticut, see the papers by Messrs. Brush and Dana.*

In closing I wish to acknowledge my indebtedness to Professor Geo. J. Brush, who has most liberally furnished me with the material needed for this examination.

Sheffield Laboratory, June 18, 1879.

Art. XL.—*On the Superposition of Glacial Drift upon Residuary Clays*; by W. J. McGee.

The accompanying actual section is exposed in a cut on the Delaware & St. Paul Railroad, a mile north of Delaware, Delaware County, Iowa. No. 1 is glacial drift, somewhat light



and sandy, but containing erratics and continuous with the mantle of "ground moraine" deposits covering the greater por-

* This Journal, July and August, 1878, and May, 1879.

tion of the State. A few fragments of chert from the underlying Niagara Limestone are scattered through the deposit. Its thickness in this section varies from one to three feet, but in the southeasterly end of the same cut it is considerably thicker. No. 2 is red clay with nodules of chert, but without sand or erratics. In no respect is it distinguishable from the residuary clays of the Wisconsin driftless region fifty miles to the eastward. Three unusually regular and uniform layers of chert are exposed, yet remaining *in situ* through the greater part of the length of the cut. They are represented at *a*, *b*, and *c*. To the northwesterly end of the cut, however, they are contorted as represented, evidently by glacial action. Still greater contortion is exhibited in the lines of original stratification which can occasionally be detected in the enveloping clay. These contortions must have strongly disturbed and corrugated the adjacent surfaces; but all trace of this was subsequently removed by the glacier.

Though these members are so diverse in character, there is no well-defined plane of contact between them, nor is the surface of No. 2 in any place, so far as observed, smoothed or striated.

The direction of glacial motion here, as determined by the position of neighboring äsar, was S. 50° or 55° E. The elevation of the section is 540 feet above the Mississippi at Dubuque.

Several analogous sections have been exposed in excavating wells two miles north of Farley, Dubuque County, Iowa, and in a cut on the Dubuque & Southwestern Railroad, half a mile southwest of the same place. Here, however, the drift is thicker and more compact than in the Delaware section, and contains a greater number of erratics; and many silicified Niagara fossils are found in the residuary clay, both free and imbedded in the nodules of chert. Aside from the thickness of the overlying beds of glacial drift we have here no positive evidence, such as is afforded by the Delaware section, that the residuary clay may not have been formed since the glacial period. Its surface has not been found to be either smoothed or furrowed.

Near Rockford, Floyd County, Iowa, there is an extensive exposure of the upper beds of the *Hamilton Limestone and Shales*,* here consisting of stiff blue and buff clays. It is the opinion of Prof. Calvin, of the Iowa State University, who has studied the formation at many exposures, that these clays were never much more firmly indurated than at present.

A section here exposed is as follows:—

1. Drift, with large bowlders,.................1 to 4 feet.
2. Clays of the Hamilton shales, about ....50 feet.

* Sometimes denominated the *Rockford shales*. For the relations of the formation, with a description of some of its fossils, see Prof. S. Calvin's papers in this Journal, vol. xv, p. 460, and in Bull. Geol. and Geog. Surv. Terr., vol. iv, No. 3, p. 325.

The ice here moved S. 20° or 30° E., and must have been of .mense thickness, as attested by the presence of northern wlders 20 to 40 feet in diameter within a few miles to the :ward; yet the subjacent clays were not seriously disturbed, evidenced by numerous absolutely perfect fossil Devonian achiopods in the clay. The ice, too, must have ascended liquely the steep slope of the bluff. A ground and striated ecimen of *Orthis Vanuxemi*, and an *O. Iowensis* with a oothed plane surface on the dorsal valve picked up from the lus at the base of the section, would indicate that the surface the clays might exhibit glaciation on fresh exposure. At e time of examination the section was much weathered.

In none of these sections, nor in any of the many others iich might be given, did space permit, are the pre-glacial ys more compact than is the lower till or blue clay found mediately below the latest formed glacial drift over the eater part of the State. It is this later drift which overlies e residuary and sedimentary clays in every instance.

The conclusions which a study of these and similar sections em to justify may be briefly stated: (1) That residuary ys (and, by inference, other clays of equal compactness) were ssed over by a thick ice-sheet (*a*) in some instances without moval or even serious disturbance, while (*b*) in other cases ey were removed, or contorted and broken up, just as the wer till and associated deposits have been found to be on th sides of the Atlantic;* and (2) that the plane of contact tween glacial drift and subjacent beds of residuary clay (and, inference, other clays of similar consistency) is not necessa- y clearly defined—the materials so intermingling as to form thin intermediate stratum of composite character. Analogy th the many recorded instances in which the upper surface the lower till is scored and smoothed† and with the "striated vements" of Hugh Miller, would, however, seem to justify the sumption that residuary clays may sometimes be smoothed d furrowed.

'arley, Iowa, July 30, 1879.

* See Lyell, "Student's Elements," 1871, p. 179, and Antiq. Man, 1873, p. 262; ll, "Climate and Time," Am. Ed., p. 465; Geikie, "Great Ice Age," Am. Ed., 144–5; Chamberlin, Geol. Wis., 1877, vol. ii, p. 219; Foster and Whitney, ol. Lake Superior Dist., 1851, pt. ii, p. 245; Logan, Geol. Can., 1863, pp. 898, l, 906; Reid, Geol. Mag., vol. vi., p. 379; LeConte, this Journal, vol. xviii, 40; Hinde, Canadian Journal, April, 1877; McGee, Proc. Am. Assoc., 1878.

† Chamberlin, loc. cit., p. 226; Lyell, "Student's Elements," p. 178; Geikie, loc. , p. 151, and also Trans. Geol. Soc. Glasgow, 1863, vol. i, pt. ii, p. 68, and Hacial Drift of Scotland," p. 67; Read, Geol. Ohio, 1878, vol. iii, pt. i, p. 312; nde, loc. cit. (striated pavements also occur near Toronto and are here de- ibed); Dawson, cited by Logan, loc. cit., p. 919; Reid, loc. cit.; Chambers', in. New Phil. Jour., vol. liv, p. 272; and Smith, "Newer Pliocene Geology," 129. The last two authorities are cited by Croll, loc. cit., p. 256.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Theory of Fractional Distillation.*—Thorpe has given a striking instance of the general law announced by Wanklyn and confirmed by Carey Lea and Berthelot, that when two liquids of different boiling points are mixed together in equal quantities by weight, and subjected to distillation, the quantity of each constituent in the distillate is proportional to the product of its vapor-density and vapor-tension at the temperature of ebullition of the mixture; and hence that when the vapor-tensions of the two liquids are inversely proportional to their vapor-densities, the liquid will distill unchanged. Berthelot, for example, observed that a mixture of 90·9 parts carbon disulphide, boiling at 46·6°, vapor-density 38, and 9·1 parts ethyl alcohol boiling at 78·4, vapor-density 23, behaved on distillation like a homogeneous liquid; the ratios obtained by multiplying the vapor-tensions and densities being 88·5 and 11·5. Thorpe's results were obtained with a mixture of equal volumes carbon tetrachloride, boiling point 76·6°, vapor-density 76·7, and methyl alcohol, boiling point 65·2°, vapor-density 15·97; and he noticed that 46·5 per cent of the whole boiled constantly between 55·6° and 55·9°, or nearly 10° lower than the boiling point of the most volatile constituent. By vapor density determinations, the composition of the mixture by weight was found to be 78·1 CCl_4 and 21·9 CH_4O; a ratio almost identical with that obtained by multiplying the vapor-tensions of the two liquids at the temperature of the boiling point of the fractions (55·7°) by their respective vapor densities. Hence a mixture of 1 part methyl alcohol and 3·6 parts carbon tetrachloride, boils like a homogeneous liquid at about 10° lower than the boiling point of the methyl alcohol, the more volatile of the two liquids. On continuing the distillation of the liquid remaining in the flask, the several fractions gave numbers showing clearly that the CCl_4, although having the higher boiling point, passed over in largest quantity in the first fractions, the quantity of pure methyl alcohol increasing as the temperature rises. Thorpe suggests, as a lecture-experiment to show the effect of such a mixture, that into one of three barometer tubes over mercury, a few drops of methyl alcohol be put, an equal quantity of carbon tetrachloride being placed in the second, and a mixture of the two in the proportion of 3 c.c. of CH_4O and 5 c.c. of CCl_4 in the third. In the first tube the mercury will be depressed about 80 mm. and in the second 70 mm.; while in the third the depression will be 130 mm.—*J. Chem. Soc.*, xxxv, 544, Aug. 1879. G. F. B.

2. *On the Solidifying point of Bromine.*—Because of the widely differing values given for the point at which bromine solidifies, Philipp, at the suggestion of Rammelsberg, has undertaken to redetermine it. In order to purify the bromine, it was

dissolved in caustic baryta water, the washed barium bromate converted into bromide by ignition, and this distilled with sulphuric acid and potassium dichromate. The distillate was washed and dried; a part by agitation with concentrated sulphuric acid and distillation and a part by distillation from calcium chloride. Thus purified, the bromine solidified between $-7{\cdot}2°$ and $-7{\cdot}3°$, phenomena of surfusion not being noticed. This result corresponds with that obtained by Regnault $-7{\cdot}32°$. The non-purified bromine solidified at $-9°$ to $-10°$. To test the influence of foreign admixture, the author made direct experiments and found that while 2 per cent of iodine did not materially raise the solidifying point, 3 or 4 per cent of chlorine lowered it even to $-15°$. Solid bromine has a brown color and a conchoidal fracture; though after exposure to the air, it takes a gray color recalling that of iodine, and appears crystalline.—*Ber. Berl. Chem. Ges.*, xii, 1424, July, 1879. G. F. B.

3. *On the Thermic formation of Hydrogen silicide and of Ethyl silicate.*—OGIER has studied, in Berthelot's laboratory, the heat-relations attending the formation of hydrogen silicide and of ethyl silicate. The hydrogen silicide was prepared by the action of sodium on tribasic siliciformic ether, and was free from hydrogen. It was burned with oxygen in the small glass chamber of a water calorimeter, being ignited by a small induction spark. The quantity of gas used was determined from the increased weight of the chamber and of a tared eduction tube filled with fragments of pumice moistened with sulphuric acid. In this way the heat of combustion of one equivalent of SiH_4 was found to be 324·3 calories. From this, since Si (cryst.) $+O_4 = +211{\cdot}1$ cal. and $4(H+O) = +138$ cal., $SiH_4 + O_8 = +324{\cdot}3$ cal. as above, we have $Si + H_4 = +24{\cdot}8$ calories. Hence in uniting Si and H_4 evolve 24·8 calories, a number very near that which the formation of marsh gas gives, $+22$.

The heat of formation of silicic ether was determined in two ways: first, analytically, by decomposing it by means of a large quantity of water, into silicic acid and alcohol, at the ordinary temperature; and second, synthetically, by forming it directly by the action of silicium chloride upon absolute alcohol. The former method gave $+21{\cdot}6$ calories as the heat evolved in the decomposition. Taken with the contrary sign, it expresses the heat absorbed in the formation of the ether from the alcohol and silicic acid. Subtracting from this the heat corresponding to the solution of the alcohol in water, there is left $-11{\cdot}44$ calories, the true heat of formation of silicic ether. The latter method showed that the heat evolved when one equivalent silicon tetrachloride acted on 26 equivalents of alcohol was 42·3 calories at 10°. Making the necessary corrections, the heat of formation of silicic ether obtained in this way, is $-11{\cdot}56$ calories, a close accordance with the number obtained analytically, $-11{\cdot}44$. Referred to a single equivalent of alcohol instead of four, it becomes $-2{\cdot}9$.—*Bull. Soc. Chim.*, II, xxxii, 116, 118, Aug., 1879. G. F. B.

4. *On Organic Ultramarines.*—DEFORCRAND has succeeded in producing an ultramarine containing ethyl. Though Unger first succeeded in replacing half of the sodium in ultramarine by silver, Heumann first produced an ultramarine in which this replacement was complete. This yellow silver-ultramarine served as the starting point in the new researches. When heated, dry, with a metallic or an organic chloride, silver chloride and a new ultramarine result. Silver ultramarine was prepared by heating in sealed tubes for 15 to 16 hours, four or five grams of blue ultramarine and 8 or 10 grams silver nitrate in concentrated solution. A beautiful yellow powder in transparent grains is thus obtained, which contains 46 to 47 per cent of silver, and has all the properties of an ultramarine. From it the blue ultramarine may be regenerated either by heating with a strong solution of sodium chloride for twenty-five hours, the reaction being then limited by the inverse one; or by heating the two without water to a high temperature, in which case the conversion is complete. If other metallic chlorides be used in place of sodium chloride, a series of ultramarines is obtained containing the metal used in place of the silver, there being a definite temperature for each at which its formation is a maximum. The potassium and rubidium ultramarines are greenish blue, that of lithium is blue, of barium yellowish-brown, of zinc violet, of magnesium gray, etc. Mercuric chloride gives a gray mercury-ultramarine when heated directly with the blue sodium ultramarine. Heated with ethyl iodide in a sealed tube to 180° for from fifty to sixty hours, and repeating the operation several times, silver ultramarine is decomposed, yielding a clear gray powder with a reddish cast, which even at 100° evolves ethyl sulphide. If, however, this powder be intimately mixed with sodium chloride before heating it, only a trifling evolution of ethyl sulphide takes place, and the mixture becomes blue owing to the regeneration of sodium ultramarine. The reaction is complete at the temperature at which the sodium chloride melts, the ethyl being evolved as chloride. That the gray powder actually contained ethyl was proved by heating a gram of it to redness in a tube through which an inert gas passed, the products being collected in a solution of mercuric chloride. A white crystalline precipitate of $(C_2H_5)_2S.HgCl_2$ was formed, thus proving the gray powder to be a true ethyl ultramarine. Similar compounds were obtained with allyl, amyl and benzyl, and with the compound ammoniums.—*Ann. Chim. Phys.*, V, xvii, 559, Aug., 1879.

G. F. B.

5. *On the Synthesis of the Benzene Ring.*—Perhaps no hypothesis in science has been more fruitful of results than the classic one of Kekulé in relation to benzene, which supposes that its six carbon atoms form a closed ring. Since the few synthetic methods, by which this ring has until now been formed, do not decide between this and the so-called prismatic arrangement of the benzene nucleus, VON RICHTER has sought for and discovered a direct synthesis of the benzene ring which strongly confirms the hypoth-

esis of Kekulé. Exactly as monobasic acids yield common ketones, so the diabasic acids should give double ketones having the carbon atoms in a ring form. Thus from succinic acid, di-ethylene-di-ketone is formed:

$$\begin{array}{l} CH_2 \diagup COOH \\ | \\ CH_2 \diagdown COOH \end{array} + \begin{array}{r} HOOC \diagdown CH_2 \\ | \\ HOOC \diagup CH_2 \end{array} \text{ gives } \begin{array}{c} H_2C \diagup CO \diagdown CH_2 \\ | \qquad\qquad\quad | \\ H_2C \diagdown CO \diagup CH_2 \end{array} + (CO_2)_2$$

$+(H_2O)_2$. The potassium, sodium, magnesium, calcium and lead salts of succinic acid were submitted to distillation under various conditions. A dark colored oil in greater or less quantity was always obtained, having a ketone-like odor, but from which no fractions of exact boiling point were obtainable. By distilling the fraction boiling between 160° and 250° with zinc dust, considerable benzene was obtained. Moreover hydroquinone was contained in the wash waters of the crude oily distillate. Since the above di-ketone yields both these bodies readily, $C_6H_8O_2 = C_6H_6O_2 + H_2$ and $C_6H_6O_2 + Zn_2 = C_6H_6 + (ZnO)_2 + H_2$, it may be considered as proved that the benzene nucleus has the constitution assigned to it by Kekulé. Moreover this experiment fixes hydroquinone as a para-compound and establishes the quinones as double ketones.—*J. pr. Ch.*, II, xx, 205, Aug., 1879. G. F. B.

6. *On the Sulpho-ethers of the Polyatomic Alcohols and the Carbohydrates.*—Claesson showed, a short time ago, that chlorsulphuric acid, $SO_2\left\{\begin{matrix}OH\\Cl\end{matrix}\right.$, acted on the monatomic alcohols to form mono- or di-sulphuric ethers. He has now extended the reaction to the polyatomic alcohols and has obtained from glycol, ethylene disulphate, from glycerin, glyceryl trisulphate, from erythrite and mannite, tetra- and hexa-sulphates respectively, and from dulcite, a penta-sulphate. The carbohydrates of the glucose group give by this treatment, isomeric compounds probably monochlor-tetrasulphates. At least this is the case with dextrose whose derivative is crystallizable and has the composition $CH_2OSO_2OH.(CHOSO_2OH)_3.CHCl.CHO$. Cane sugar, starch, etc., are first inverted and then the above compounds are formed. These polysulphates of the optically active alcohols and carbohydrates have an increased rotatory power to the right. Milk sugar gives dextrose and galactose.—*J. pr. Ch.*, II, xx, 1, Aug., 1879.

G. F. B.

7. *On the Conversion of Aurin into Trimethyl-pararosaniline.*—Dale and Schorlemmer, by acting on aurin with ammonia, have sought to obtain the intermediate products between this substance and para-rosaniline. As ammonia gave so much trouble, they tried methylamine and found that in aqueous solution, this base acts readily on aurin at 125° and transforms it almost entirely into a purple body, possessing all the properties of a trimethyl-rosaniline: $C_{19}H_{14}O_3 + (CH_3NH_2)_3 = C_{19}H_{14}(CH_3)_3N_3 + (H_2O)_3$. Trimethylamine acts similarly, converting the aurin into purple coloring matters.—*J. Chem. Soc.*, xxxv, 562, Aug., 1879.

G. F. B.

8. *An Induction Balance.*—Professor J. E. Hughes has lately devised an instrument which promises to be of great use in determining the amount of the constituents of alloys. It is based upon the principle that the induced current in a secondary coil depends upon the character and amount of metal which forms the core of the primary. A portion of the apparatus Professor Hughes calls a sonometer; this consists merely of two primary coils which are placed with opposing poles about a meter apart on a divided scale. Between them slips a secondary coil which is connected with a telephone. If the primary coils are exactly equal, and are traversed by the same electric current, one will hear no sound when the secondary coil is exactly between the primary coils. This point of balance is called the zero of the sonometer. The circuit running through the primary coils is provided with a microphone, and a clock ticking upon the support of the microphone supplies the necessary change of resistance in the electric circuit. If the equality of the sides of the sonometer is disturbed by the introduction of metals on one side or the other, the telephone announces the inequality and the secondary coil has to be moved nearer one primary coil than another. The number of degrees moved is a relative measure of the difference of the metals. The extreme sensitiveness of this balance is shown by numerous experiments. It is also of use as a coin detector—any difference in the quantity or quality of the metal being instantly shown. W. Chandler Roberts, Chemist of the Mint, has tested Professor Hughes' balance, and gives a number of curves produced by different alloys, and shows that the balance can detect smaller quantities of metals in the composition of alloys than the methods hitherto used. He suggests also "that the balance may afford a simple means of detecting variations in the molecular structure of alloys and for detecting allotropy in metals with greater accuracy than has hitherto been possible."—*Phil. Mag.*, July, 1879, p. 50. J. T.

II. Geology and Natural History.

1. *Notice of Volcanic Phenomena and Earthquakes during* 1878.—The statistical review of these phenomena recently published by Professor C. W. C. Fuchs shows the unusually large number of *twelve* eruptions during the year; most of which occurred in remote localities and from little known volcanoes. In Vesuvius there was but slight activity, with a small flow of lava in September and November. On January 10, smoke was seen from two hitherto unknown volcanoes at the southern point of South America. On the same day a great eruption occurred in the island of Tanna, one of the New Hebrides, followed by a second outbreak on February 4. Simultaneously yet another eruption occurred in the island of Birara in the group of New Britain. Another eruption took place in February from the volcano Isluga in South America (lat. 19° 10′ S.), where several villages were destroyed by the lava streams and accompanying

earthquake. Other eruptions were from Mount Hecla (March), from the Asamayama in Japan, from Cotopaxi (October), from the Tepaco, the Sitna, and the Isalco in San Salvador, from the volcanoes of the Aleutian Islands and in the Society Islands. Dr. Fuchs also records the great mud eruption near Paterno in Sicily, which began on Dec. 10, and still continued at the end of the year.

The number of earthquakes reported during 1878 amounts to 103. But among these are many complete earthquake periods during which the shocks continued with short intervals for hours, days or even weeks in the same locality. If every shock were counted the total would be many times greater.

The earthquakes were most frequent in winter and autumn—thirty-nine occurring in winter, twenty-six in autumn, and nineteen each in summer and spring. The most violent and destructive earthquakes occurred on January 23 in Peru and Boilvia, and on October 2 in San Salvador. (Also on April 12 in Venezuela. This Journal, Feb., 1879, pp. 158, 159, 161.) Of European earthquakes the following deserve notice. On January 28, about noon an earthquake occurred in the northwestern part of France and the south of England, particularly distinct in Normandy. Repeated shocks were felt in northwestern Switzerland and the southwest corner of the Black Forest on January 16, 17 and March 29. Other instances of repeated earthquakes are Innsbruck (Jan. 3, 10, 11, Feb. 2, Aug. 9), Gross Geran (Jan. 2, March 25), Lisbon (Jan. 26, 27, June 8), Constantinople and vicinity (April 19 to end of May). Less remarkable for its violence than for its extent was the Low-Rhenish earthquake of Aug. 26. The observations in this case were unusually exact and numerous, which gives additional interest. It began about 9 A. M., and was best observed in Cologne. Here it consisted of an undulatory rising and sinking of the ground, which increased in intensity to an alarming extent. On the cathedral tower the smaller bell struck several times, and in many places the houses showed cracks. At the end of the oscillations a dull subterranean noise was heard, and a second shock was observed by many persons. At other places the phenomena were similar. The area affected by the first shock may have measured over 2000 geographical square miles, as its outlines may be indicated as follows: Arnsberg and Hanover on the north, Offenbach on the Main and Michelstadt in the Odenwald on the southeast, Strasburg, Paris and Charelville in the south, Liége and Brussels in the west, and Utrecht in the northwest.

From collating the most reliable observations of time Professor Klinkerfues infers that the velocity of the earthquake in the ground was 6·78 geographical miles per second, and that its origin was between 6·3 and 8·7 miles below the surface.

It is remarkable that the phenomenon was only noticed at the surface and was more intense the higher the observer was above the ground, while miners working at a depth of 300 meters did not feel it at all.

A similar fact has been noticed in regard to some recent earthquakes in our Rocky Mountain region, which, though quite severe on the surface were not felt in the mines below.—*Condensed from Nature*, Aug. 14, 1879. C. G. R.

2. *The Geology of the Diamantiferous Region of the Province of Paraná, Brazil;* by ORVILLE A. DERBY, M.S. (Proc. American Phil. Soc., May 16, 1879.)—This paper records the results of a recent trip by Mr. Derby, to the Province of Paraná, in continuation of the labors of the late Geological Commission in the same region; and it also gives us for the first time an accurate idea of the relations of the deposits of extreme southern Brazil to those of the other parts of the Empire. The Province of Paraná, one of the more southern ones of Brazil, lies between the provinces of São Paulo and Santa Catharina, and reaches from the Atlantic to the Rio Paraná. In its topographical and geological features it resembles, to a certain extent, the two provinces which border it on the north and south. The coast range of mountains, or Serra do Mar, traverses it in a north-south direction, leaving along the coast a low belt, from ten to twenty miles broad. The remainder of the province is, strictly speaking, a plateau, from 800 to 1000 meters high; but Mr. Derby divided the entire province into two distinct topographical regions, a mountainous region, bordering the coast and extending inland about 100 miles, and a plateau region, occupying the central and western parts of the province. The first region is entirely composed of metamorphic rocks, highly inclined and with a general strike east-northeast. These, in the coast belt, and in the Serra do Mar proper, are mostly granites and gneisses, representing the Archean of Rio de Janeiro and northern Brazil; but further west they consist principally of metamorphic schists, quartzites, marbles, etc., and represent the Lower Silurian or Cambrian of Bahia, Minas Geraes and northern Brazil. A second geological province extends from the metamorphic westward, a hundred miles or more, forming the far-famed "Campos Geraes," and made up of shales and coarse and fine sandstones. In the shales of this group at Ponta Grossa, were discovered species of *Lingula*, *Discina*, *Spirifera*, *Rhynchonella*, *Streptorhynchus* and *Vitulina*, strongly resembling, and probably identical with, those of the Devonian of the Amazonas. Other fossils were also obtained. The entire western part of the province is apparently formed of a heavy bed or series of beds of trap, overlying a considerable thickness of soft red sandstone, which, in turn, overlies the shales and sandstones of the second region. The rocks of the third region resemble in a striking manner the Triassic rocks of North America.

The diamonds are found principally in the valley of the river Tibagy, and more rarely in other river valleys, as they cross the second or Devonian area, above defined. The observations made tend to prove that the sand and gravel containing the diamonds were derived from the underlying Devonian sandstones, which had previously obtained their material from the lower-lying meta-

morphic series. The gems are found in the sands of the river, and in more elevated gravel banks, called "dry washings." R. R.

3. *Serpentine Marble.*—A beautiful variety of mottled serpentine marble is worked at a point on Broad Creek in Harford county, on lands of the Havre Iron Co., Maryland. Dr. Genth states that there are three beds of serpentine, associated with chloritic and other magnesian rocks in the mica schist formation of the region. The chief bed is about 500 feet thick, and is traceable by its outcrop for about 1500 feet.

4. *The Gymnospermy of Coniferæ;* by Dr. L. CELAKOVSKY. A paper in *Flora* for June, 1879, Nos. 17 and 18.—Celakovsky, who takes a high position as a morphological botanist, mentions that in the year 1874 he published in *Flora* an article opposing gymnospermy. He now announces that he has changed his opinion, having satisfied himself of the truth of this doctrine. The agent of conversion was a monstrosity of the Norway Spruce cone, like that from which Stengel made out the now accepted morphology of the cone, and the same monstrosity as that which Braun studied in the Larch, deducing from it the accepted doctrine many years ago. The essential point in this monstrosity is that the bracts of the abnormal catkin develop into leaves, and the carpellary scale before it into a pair of leaves transverse to the bract. The abietinous carpel consists of these two leaves united by their posterior edges (i. e., those next the axis of the cone) into a scale, the back of which therefore faces the axis of the cone, and bears the ovules. The lower part of these catkins is usually normal, the apex by prolification is gradually transformed in the manner here specified, and becomes a leafy branch. Dr. Engelmann, in this Journal, three years ago, gave a confirmatory account of an analogous monstrosity in the Hemlock Spruce, but in which the transformation was at the base of the cone, the lower bracts leaf-like and with a pair of leaves in their axil, the following bracts more and more scale-like, the geminate leaves in their axil were partially united, next forming a scale with a cleft or notched apex, then an entire carpellary scale, in the axil of a normal bract.

Celakovsky, having now seen the Spruce monstrosity for himself, adopts the inevitable conclusion, and applies it well to the settling of the question of gymnospermy. He declares that the dorsal origin of the ovules of the Abietineæ proves that it is no axillary production, and thus the main support of those who take the ovule for a simplified female flower falls to the ground. Moreover, the ovules of Coniferæ in retrograde metamorphosis never change into shoots, but simply disappear. If flowers, they would be expected sometimes to become foliaceous branchlets. So Celakovsky regards it as demonstrated that they are outgrowths from the dorsal face of the leaf, analogous to the sori and indusia of Ferns. He cites the indusium of *Hymenophyllum* as an instructive analogue, only it is marginal; that of *Davalia* is somewhat dorsal; that of *Cyathea* wholly so and yet cup-shaped. He goes on to say that the gymnospermy of *Abietineæ* being thus proved, that of the rest

of *Coniferæ* follows of course; that Braun has seen similar prolification in the catkins of *Taxodineæ*, in which the carpel-scale was replaced by a bud; that, although the carpel-scale in *Abietineæ* consists of two leaves, the bud may in other cases develope more than two leaves, so that the lobed scale of *Cryptomeria* may be composed of as many leaves as there are lobes. Moreover, although the ovules in *Abietineæ* originate from the scale, the greater part of the scale is developed after the formation of the ovules; and in *Cupressus* the scale is developed even as late as the following spring, while the ovules are produced in the autumn. However the case may be disguised, Celakovsky asserts his firm conviction, 1st, that an ovule can only be developed as depending on a carpel, and, 2d, that its nucleus represents the macrosporangium of vascular Cryptogams. He adds that this is the logical consequence of the theory of descent, and must be true if the doctrine of the genetic connection of the vegetable world is true. He considers that Van Tieghem and Strassburger have proved the seemingly simple scale of *Cupressineæ* and *Taxodineæ* to be composed of bract and carpel-scale united [which indeed is evident in *Taxodineæ*], and that Braun has confirmed this by the study of proliferous cones. As to the development of ovules earlier than the carpels they belong to, this is said to have been observed in some Angiosperms also, as in *Cuscuta*, in which at first four naked ovules appear. The anatomical organogenist may argue from this that ovules and carpels are independent productions, but Celakovsky insists that he will argue wrongly.

This brings our author to the consideration of the structure of *Taxineæ*. This is environed with difficulties, and explanation is only conjectural. Here the disc, arillus, cupula, or whatever it be called, makes its appearance where no trace of carpellary scale is to be seen. Celakovsky inclines to the view that this organ, occurring in whatever form, is most probably the carpellary scale itself, very tardily developed. In *Dacrydium* the cupule is homologous with that of *Taxus*, but oblique. *Cephalotaxus* has no scale and no cupule, but seems to correspond with *Cupressineæ*, and shows at maturity a small flattened rudiment between the two ovules, which is probably a rudimental carpel-scale. *Gingko* is the most puzzling; yet it seems probable that the biovuliferous peduncle represents the abietineous carpel-scale, the peduncle itself being its elongated base. The cupule of Taxus may be either a simple circular carpel, or may consist of more than one carpel. The apparently terminal ovule of *Taxus* and *Torreya* he would regard as axillary to one of the uppermost subtending bract-scales; for he will not concede that the ovule can be wholly destitute of a carpellary organ. Yet he might do so, in one sense; for if the carpel may develope very late and very imperfectly or very little, it may sometimes not visibly appear at all, and so the phyllome be reduced to the ovular outgrowth.

Finally, Celakovsky notes, that if the ovule of *Taxus* and *Torreya* be axillary to an uppermost scale, it would originate not from the dorsal but from the ventral face, i. e. from the upper side

of the leaf; which would distinguish *Taxineæ* from all true *Coniferæ*,—a view which would not be destitute of important support. For both Braun and Mohl have seen apparently androgynous scales in some *Abietineæ*. In a monstrous Larch-ament, among carpellary scales with normally dorsal ovules, Braun found one with ovules on the opposite face; and Mohl describes and figures an androgynous inflorescence of White Spruce, with pollen-sacs on the outer face, and on the other a pair of knobs which from their form and position might be taken for imperfectly developed ovules. But this latter case seems most ambiguous. If it was in a male catkin, the upper part of which had become female by the development of carpel-scales in the axil of stamens partially transformed into bracts (which is the case we have before us in a monstrosity of Hemlock Spruce), then the quasi-androgynous scale in question may have been the normal abietineous carpel-scale itself, with the polleniferous bract behind it and connate with it.

The androgynous spike of Hemlock Spruce before us is below normally staminate; above some anthers are slightly scarious-winged at one side of the projecting tip, another has this wing developed into a bract-like body on the whole of one side; next there is a bract with a single small pollen-sac on one side of its back and in its axil a well-formed and biovulate carpel-scale.

G. E. & A. G.

5. *Contributions to American Botany*, IX; by SERENO WATSON. From *Proceedings of American Academy of Arts and Sciences*, vol. xiv, July, 1879, p. 213 to 303, and an index.—Mr. Watson, in preparing the Monocotyledoneæ for the Botany of California, came upon the order *Liliaceæ*, which is well represented in Pacific North America; and he had to consider how the genera and higher groups should be disposed. This led to a wide study of the order and a strict scrutiny of the American species; and the present "*Revision of the North American Liliaceæ*," occupying the greater part of the "Contribution" before us, is the result. It is generally agreed that this order is to have the wide extension which was given to it by the present writer a dozen and more years ago; and the proper collocation of its diversified forms, with interlaced affinities, has been a problem of no small difficulty. Mr. Baker, in England, has attempted the task for the order generally, and has sedulously elaborated some of the North American, but more of the Old World and the South American, genera and tribes. His arrangement and his systematic views are in many respects satisfactory, in some unsatisfactory as respects North American botany. Mr. Watson has the latter primarily in view, but still has to adjust the American genera into the general system. The arrangement he has planned consists of three *series*, the first of which parts into two *subseries*, and includes sixteen tribes, some of them divided into subtribes. The great endeavor has evidently been to make natural groups—and this endeavor has been really successful. The next thing is to assign characters, and here comes the difficulty. Absolute

characters of the leading groups are not to be had, even when North American forms only are considered. Those who imagine they could do better than Mr. Watson has done should make trial before they criticise. The character of the pericarp, whether baccate or capsular, the nature of the stock, whether bulbous, tuberous or rhizomatous, the nature of the seed-coat, the inflorescence, direction of anthers, union or separation of styles, are all good characters to a certain extent, and all fail to furnish unexceptionable marks to distinguish the higher groups when natural associations are sought. It is not easy to ascertain what diagnostic characters in this monograph are most to be trusted. But the nature of the bracts (on the one hand scarious, on the other foliaceous or none) takes the lead in the first two series, and is followed by the persistence or deciduousness of the perianth, the insertion of the stamens whether on the perianth or at its base, the dehiscence of capsule,—all matters of little physiological importance, but for that reason perhaps surer guides to affinity than the more prominent adaptive characters. However, it may be said that the first series answers to the *Asphodeleæ*, with *Yucca* and *Hemerocallideæ* added; the second to the true *Liliaceæ* with *Uvularieæ* and *Trillieæ* added; the third to *Melanthaceæ*, with the tribe *Tofieldieæ* appended. Thus disposed, it is doubtless judicious to designate the three primary groups as "series," and not as suborders, and to throw the stress upon the tribes.

The Melanthaceous series, which in our view best divides into the *Colchiceæ*, *Veratreæ* and *Tofieldieæ*—the first not American—is here divided into the *Veratreæ*, *Helonieæ* and *Xerophylleæ* (which two we should combine), into the midst of which the *Tofieldieæ* are intercalated. This last tribe, which should end the series, is quite exceptional, and is well composed of *Tofieldia*, *Pleea* and *Narthecium*. Its marks are the equitant leaves, introrse anthers with parallel cells, and caudate seeds; but to bring *Narthecium* under the remaining character of "styles distinct or none," it is defined as destitute of style, but with "the slightly lobed stigma sessile upon the attenuated apex of the ovary." This is really much nearer the fact than would be supposed, as the cells of the ovary actually do taper up into the subulate style (as it has always and most naturally been termed), so that in the mature capsule the upper tails of the seeds reach up to within a short distance of the small stigma.

In a linear order it has not been practicable to approximate the *Convallarieæ* of the first series with the *Uvularieæ* of the second. The division of *Uvularia* gives a gratifying opportunity of dedicating a New England genus to the memory of one of the best of New England botanists, the late Wm. Oakes (*Oakesia sessilifolia*, with its relative of the southern mountains, *O. puberula*); but he would not have relished the dismemberment of the Linnæan genus upon the characters, good as they are, neither in fact do we. The formation of the tribe *Yucceæ*, of *Yucca* and *Hesperaloe*, strikes us as excellent; and it seems right not to adopt the supposed second species of *Hesperaloe* until it is better known. Its

principal distinctions (longer anthers and shorter style) may indicate heterogone dimorphism, which would be a novelty in the order.

Tribe *Nolineæ*, of the first series, must be regarded as an excellent group, composed of *Dasylirion* and *Nolina;* and it is gratifying to find that the outlying genus, *Nolina*, founded long ago, on a single Georgian species, is the northern representative of a considerable Texano-Mexican group, named *Beaucarnea*. It were to be wished that the plan of this Revision had allowed more citation of generic synonymy, and that it had been more explicitly stated that *Beaucarnea* is only *Nolina*. This union, indeed, is one of the happy hits of the present monograph.

As has been suspected, the Californian *Schœnolirion album* of Durand proves to be quite distinct from the Atlantic species on which that genus was founded. So Mr. Watson has embraced the opportunity, here offered, to dedicate a peculiar Californian genus to Judge Hastings—a judicious patron both of botanical and legal learning. Except for his exertions, his own liberality and his direction of the liberality of others, we could not have had the Botany of California, which Mr. Watson may now soon bring to a completion. The reader finds no mention of this under the genus *Hastingsia*, p. 217, nor under the species, *H. alba*, p. 242. But an appropriate reference is made on p. 286.

Leucocrinum, Nutt., was conjectured by Endlicher to be the Mexican *Weldenia*, but it has just now been ascertained at Kew that *Weldenia* is a Commelynaceous genus.

Our species of *Allium* as now worked out by Mr. Watson with great painstaking, are thirty-six in number, exclusive of the introduced *A. vineale*. Some characters might be made more of in living plants, such especially as those furnished by the so-called "crests of the ovary." In *A. stellatum* these crests are remarkably developed, radiating from around the base of the style and recurving, the notch at the end of each fitting over the base of the alternate filaments, and the under side is nectariferous and attractive to bees. The flowers are proterandrous.

In separating the two species of *Maianthemum* we should have unhesitatingly referred the large Pacific coast form to *M. bifolium*. We should not have distinguished *Lilium Grayi* as more than a form of *L. Canadense*, one which extends northward to the central parts of New York. In view of geographical range, size, and general appearance, we should never have thought of *Uvularia flava* as a synonym of *U. grandiflora*. Mr. Watson finds good characters in the shape and markings of the capsule to separate *U. grandiflora* from *U. perfoliata*. Has any one ripe fruit of the small, yellow-flowered, *U. flava?*

Chamælirium Carolinanum, Willd. This specific name is properly restored. It was the original name under this genus; and the name *luteum* is a false one (though the plant was *Veratrum luteum* of Linnæus), the blossoms being white without a tinge of yellow, duller white in the female plant, pure white in the male, the pedicels equally of this color.

No space is left in which to notice the Notes upon the Affinities and geographical Distribution of *Liliaceæ*, nor the Descriptions of Some new Species of North American Plants, about fifty in number, which make up the second part of this important "Contribution." Among them is a new *Bolandra* and a new *Sullivantia* from Oregon, both very much like (we fear too like) the original species. Here and in the Bibliographical Index, the name *Sullivantia Ohionis* is changed (perhaps accidentally) to *S. Ohioensis*. We know of no law against genetive names of geographical more than of other places or stations, and such are not extremely uncommon. The name *Ohionis* was purposely chosen, and we hope may be retained.

The interesting new Erigoneous genus *Hollisteria*, discovered by the enthusiastic Mr. Lemmon (in San Luis Obispo Co., east of the Coast Range) is of rather doubtful interpretation as to some points of structure. The inflorescence we suppose to be only seemingly axillary, the involucre is possibly a genuine trimerous one, and we take the two small stipule-like leaves to be real stipules,—a point which the published character does not decide, though it is implied in describing the leaves as alternate.

Being one of the most important of recent contributions to North American Botany, this publication deserves even a fuller notice than we can here give it. A. G.

6. *Musci Fendleriani Venezuelenses.*—Among the collections made by Mr. Augustus Fendler in Venezuela, in 1854–5, was a very fine one of the Mosses of the region which he explored. It was purchased by the late Mr. Sullivant and in part studied by him, and drawings of a large number of the species were made by Mr. A. Schrader under his direction. With the exception of a single set, accompanying the drawings, which was bequeathed to the Herbarium of Harvard University, the whole collection was made over to Mr. Schrader, the draughtsman, to be distributed by sale among the bryologists. But, as a very large proportion of the species were new, it was desirable that they should all be authentically named, and the new ones described before the sets were offered. This has now been satisfactorily and most obligingly done by Dr. Karl Müller of Halle, the accomplished author of the Species Muscorum, and publication made in the Linnæa (xlii, parts 5 and 6), this giving the highest value to the collection. Mr. A. Schrader, of Columbus, Ohio (234 West State street), now offers these sets to botanists, at $12 for the 145 species, in good specimens, with a printed form of ticket bearing the numbers, and a copy of Dr. Müller's memoir (in Latin) in the Linnæa, enumerating and describing them. There are thirty-nine sets, all of equal completeness and value. To secure them early application should be made to Mr. Schrader. A. G.

7. *Dictionnaire de Botanique ;* par M. H. BAILLON.—The first part of the second volume has appeared, containing articles from *Chlœnacées* to *Cistus*. No small part of the eighty pages are occupied by two articles, *Chlorophylle* and *Circulation*, each as it were a treatise. A. G.

8. *Miscellanea.*—The following are the more important botanical blications which have accumulated upon our table:

Transactions of the Linnean Society of London. Second ries, parts 5 and 6, of vol. i.—These contain Casimir DeCanlle's paper on the geographical distribution of the *Meliaceæ*, th a map; New British *Lichenes* by Leighton, with a fine ıte; *Liliaceæ* and other petaloideous Monocotyledons of Weltch's Angolan Herbarium, by Baker; New Zealand *Lichenes*, Knight; the fine paper on the morphology of *Primulaceæ*, by ısters; a new genus of parasitic *Algæ* and conidial fructificaın in the *Mucorini*, by D. D. Cunningham; Fungi from Queensıd, by Berkeley and Browne, and the Rev. George Henslow's ɛmoir on self-fertilization in plants, which has been reviewed in is Journal at some length.

Nouvelles Archives du Museum.—The first volume of the ɔond series begins with Decaisne's full and interesting monoaph of *Ligustrum* and *Syringa*, with three plates. There are ːrty-seven species of *Ligustrum*, and eleven of *Syringa*, includɡ *S. Amurensis* and two allied species with rotate corollas, the nus *Ligustrina* of Rupprecht.

Rivista Botanica dell' Anno 1878, di FEDERICO DELPINO, 1879, ːtr. Ann. Scientifico Italiano, Ann. xv.—A general review of tanical publications of 1878. Signor Delpino, now Professor Botany in the University of Genoa, sends us also continuans of his valuable papers on dichogamy of flowers, and some ıer interesting essays, which we hope to review later. A. G.

III. ASTRONOMY.

1. *Ephemeris of the Satellites of Mars for Oct. and Nov.*, 1879. The following ephemeris, computed from Prof. Hall's elements the satellites of Mars, gives the approximate position angles ɪ distances of the satellites about the time of elongation. Only ː times of those elongations are given which may be observed America. On Nov. 1 the probable error of the computed angle position is for Deimos $\pm 0°.6$ and for Phobos $\pm 8°.1$.

Deimos.

Date.	Wash. M. T.		Pos. Ang.	Dist.	Date.	Wash. M. T.		Pos. Ang.	Dist.
	h	m	°	"		h	m	°	"
Oct. 10	10	46	232·		Oct. 30	15	34	232·	
12	8	13	52·1	60 80	Nov. 1	12	0	52·7	66·88
13	14	31	52·		3	9	27	232·	
15	12	58	232·		4	15	45	232·	
17	9	25	52·	62·2	5	6	54	52·	
18	15	43	52·		6	13	12	52·	
20	13	10	231·		8	10	38	231·	66·6
22	10	37	51·3	63·73	9	16	56	231·	
23	16	55	51·		10	8	5	51·	
25	14	22	231·		11	14	23	51·	
27	11	49	51·		13	11	50	231·	
29	9	16	232·	65·	15	9	17	50·8	64·88

Phobos.

Date.	Wash. M. T.		Pos. Ang.	Dist.	Date.	Wash. M. T.		Pos. Ang.	Dist.
	h	m	°	"		h	m	°	"
Oct. 10	8	2	55·	24·5	Oct. 28	8	30	234·	
	11	53	235·			12	19	54·	
	15	41	55·			16	9	234·	
11	7	0	55·		29	7	28	234·	
	10	50	235·			11	17	54·	
	14	39	55·			15	7	234·	
12	9	47	235·		30	10	15	54·	
	13	37	55·			14	5	234·	
13	8	45	235·		31	9	13	54·	
	12	35	55·			13	2	234·	
	16	24	235·		Nov. 1	8	10	54·	
14	7	43	235·			12	0	234·	26·8
	11	32	55·			15	50	54·	
	15	22	235·		2	7	8	54·	
15	6	41	235·			10	58	234·	
	10	30	55·			14	47	54·	
	14	20	235·		3	6	6	54·	
16	9	28	55·			9	56	234·	
	13	18	235·			13	45	53·	
17	8	26	55·		4	8	53	233·	
	12	15	235·			12	43	53·	
18	7	23	55·			16	32	233·	
	11	13	235·		5	7	51	233·	
	15	3	55·			11	41	53·	
19	6	21	55·			15	30	233·	
	10	11	235·		6	6	49	233·	
	14	0	55·			10	38	53·	
20	9	9	235·			14	28	233·	
	12	58	55·		7	5	47	233·	26·8
21	8	6	235·			9	36	53·	
	12	16	55·			13	26	233·	
	15	46	235·		8	8	34	53·	
22	7	4	235·			12	24	233·	
	10	54	55·	26·0		16	13	53·	
	14	43	235·		9	7	32	53·	
23	9	51	54·			11	21	233·	
	13	41	234·			15	11	53·	
24	8	49	54·		10	10	19	233·	
	12	39	234·			14	9	53·	
	16	28	54·		11	9	17	232·	
25	7	47	54·			13	6	52·	
	11	37	234·			16	56	232·	
	15	26	54·		12	8	15	232·	
26	6	45	54·			12	4	52·	
	10	34	234·			15	54	232·	
	14	24	54·		13	7	12	232·	
27	9	32	234·			11	2	52·	
	13	22	54·		14	10	0	52·	26·2
						13	49	232·	

IV. Miscellaneous Scientific Intelligence.

1. *American Association.*—The twenty-eighth annual meetin of the American Association for the Advancement of Science wa held at Saratoga, during the week from August 27th to Septemb

3d. The President of the meeting was Professor George F. Barker of Philadelphia; the Vice Presidents, Professor S. P. Langley of Alleghany and Major J. W. Powell of Washington; the chairman of the Sub-section of Chemistry, Professor Ira Remsen of Baltimore, and of that of Microscopy, Professor E. W. Morley of Hudson, Ohio.

The officers of the local Committee were Dr. R. C. McEwen, Dr. J. L. Perry, Professor H. N. Wilson, Lt. Commander A. R. McNair, Professor L. S. Packard. They with the other gentlemen associated with them were highly successful in their arrangements for everything connected with the main purpose of the Association, as well as for the comfort and entertainment of the members. Under their auspices excursions were taken to Luzerne, to Lake George, to the Ausable Chasm, to Port Henry, and to other points of interest.

Of the various addresses delivered in the evenings, first to be mentioned is that of the retiring President, Professor O. C. Marsh, on the "History and Methods of Palæontological Discovery." This will be printed in the next number of this Journal. Other addresses were delivered by the Vice Presidents S. P. Langley and J. W. Powell on Friday evening, August 29; Saturday, August 30, by Dr. T. A. Edison on the "Electro-chemical Telephone."

The next meeting is to be held at Boston on the last Wednesday in August, 1880. The officers appointed for the meeting are: President, Lewis H. Morgan of Rochester; Vice President of Section A, Professor Asaph Hall of Washington; Vice President of Section B, Professor Alexander Agassiz of Cambridge; Chairman of Sub-section C, John M. Ordway of Boston; Chairman of Sub-section E, Major J. W. Powell of Washington.

The following is a list of papers which were read or accepted for reading in the different sections.

I. *Mathematics, Astronomy and Physics.*

Experimental Determination of the velocity of light, A. A. Michelson.

The comet of 1771: investigation of its orbit, W. Beebe.

Some observations on the depth of snow compared with the depth of the water it yields, J. Brocklesby.

Statement of generalization reached in question in intersection of circles and intersection of spheres: results stated, not the geometrical discussion, B. Alvord.

Meteoric constitution of the sidereal universe: I. Cooling of the sun, B. Pierce.—II. Cooling of the earth, id.

On a curious case of crystallization of Canada balsam, G. F. Barker.—On the conversion of mechanical energy into heat by magneto-electric machines, id.

A general law indicating the location of planets, satellites, or annular rings around their primaries; also its utility, S. Marsden.

On experimental solution of a problem in the doctrine of chances, T. C. Mendenhall.

Solubility of ozone, A. R. Leeds.

Modification of the glass-plate polarimeter, A. W. Wright.—Influence of light on the electrical conductivity of metals, id.

On the use of glass circles for meridian instruments and of glass bars for standards of length, W. A. Rogers.—First results from a new diffraction ruling engine, id.—On a standard meter and its subdivisions into equal parts, id.—On the coefficient of expansion of nickel-plated bars, id.—On the tremors communi-

cated to transit piers and clock piers through the walls of an observatory building, id.

Observations of double stars, ASAPH HALL.

Star places, LEWIS BOSS.—Solar parallax from minor planets at opposition, id.

On determination of errors of form of the pivots of meridian instruments, C. A. YOUNG.

On the color correction of achromatic telescopes, WM. HARKNESS.

The past state of the world's metrology as bearing on the progress of science, F. A. P. BARNARD.

New methods of Photometry as applied to electric light. P. H. VAN DER WEYDE.

A table of remainders of 2^n to various prime moduli, E. P. AUSTIN.

On the identity of the lines of Oxygen with bright solar lines, as shown in photographs taken with increased dispersion, HENRY DRAPER.

On a trigonometrical view of the calculus, J. TROWBRIDGE.

On a resonant tuning fork, T. A. EDISON.—On the phenomena of heating metal in vacuo by means of an electric current, id.

A surface upon which the "non-euclidean geometry" finds its interpretation, A. W. PHILLIPS.

Test of faradic machines, F. R. UPTON.

Upon the methods of exploring the field of induction of flat spirals, A. G. BELL.—Upon residual induction, id.—Upon binaural audition, id.

Observations of the transit of Mercury, 1878, May 6, including a systematic search for a satellite, and measures of the diameter of the planet, D. P. TODD.

On the strength of American timber, R. H. THURSTON.

On explosive and detonating compounds, B. S. HEDRICK.

A study: forms of energy, J. D. WARNER.

II. *Chemistry.*

Action of ozone upon the coloring matter of plants, A. R. LEEDS.—Bleaching of sugar syrups by ozone, id.—Reduction of carbonic acid by phosphorus at ordinary temperatures, id.—Oxidation of carbonic acid by air over phosphorus at ordinary temperatures, id.

Household chemistry, ELLEN H. RICHARDS.

On the deterioration of library bindings, W. R. NICHOLS.—Observations on the variations in the temperature and chemical characters of Fresh Pond, Mass., id.—On an accidental contamination of a source of water supply, id.

Percentage of sugar in sap of the sugar maple, H. M. WILEY.—A modified method of collecting and measuring gases soluble in water, id.

Details of the construction of an apparatus for the analysis of gases, E. W. MORLEY.—Results of systematic analyses of air, designed to discover the cause of variations in the quantity of oxygen therein contained, id.

Preliminary notice of the revision of the atomic weights, F. W. CLARKE.

On graphite from the Ducktown copper mine, W. L. DUDLEY and F. W. CLARKE.

Method of coloring, cutting and polishing agates, etc., at Oberstein, Mrs. E. A. SMITH.

Note on a peculiar case of corrosion of the metal tin, J. W. OSBORNE.

On the limits of meteorological conditions governing the extension of beet root culture, W. McMURTRIE.

On the action of caustic alkaline solution on glass, A. A. BRENEMAN.

A chemical examination of black ozokerite, C. G. WHEELER.

Exhibition of crystals of sapphire from the gem beds of Ceylon, with brief remarks, A. C. HAMLIN.

III. *Geology, Zoology, Botany.*

The succession of glacial deposits in New England, W. UPHAM.

On the thinning and absence of Upper Silurian and Devonian formation in Tennessee, J. M. SAFFORD.

Recently discovered cupreous veins at Blue Hill, Me., C. H. HITCHCOCK.

On the histology of insects, C. S. MINOT.—On the conditions to be fulfilled by a theory of life, id.—On the anatomy of Plathelminths, id.

t biography of the Menhaden, G. BROWNE GOODE.
fertilization of Yucca, T. MEEHAN.
›phy of the pupation of butterflies, and particularly of the Nymphalidæ,
EY.—The cotton worm in the United States, explanation of its work,
ed points in its habits cleared up, id.
›gies in the Lauraceæ, L. F. WARD.—Sexual differentiation in *Epigæa*
—Note on the movement of the stamens of Sabbatia angularis, id.
emarkable crinoidal form recently discovered in Tennessee, with exhibi-
ecimens, J. M. SAFFORD.
ına of the Lower Helderberg group, in relation of the Corals, Bryozoa and
rmata, JAMES HALL.—Notes upon the genera Fenestella, Hemitrypa,
On the present condition of the work upon the palæontology of New

ıe pre-Cambrian rocks in America and Europe, T. STERRY HUNT.—On
gy of Port Henry. N. Y., id.
wly discovered cave in Luray, Page Co., Va., J. W. CHICKERING, Jr.
n sand, A. P. S. STUART.
eroceanic canal problem, E. P. LULL.
progress of the second geological survey of Pennsylvania, J. P. LESLIE.
of the occurrence of rocks representing the Marcellus shales of New
Central Ohio, R. P. WHITFIELD.
ı of sex and of odor in flowers, T. MEEHAN.
genus Pleurotomaria, W. H. DALL.—On the molluscan dredgings in the
Iexico and vicinity by the U. S. Coast Survey steamer Blake in 1877–9, id.
species of Bornean Orangs, with notes on their habits, illustrated by
s, W. F. HORNADAY.
occurrence of microscopic crystals in the vertebra of the toad (*Bufo
us*). [With a note by A. A. Julien.] H. C. BOLTON.
anthracite coal fields of Pennsylvania and their rapid exhaustion, P. W.

ıvelopment of the neuration in the wings of insects, as illustrated in the
cockroaches, S. H. SCUDDER.
d-blight insect, W. S. BARNARD.
ıaratus for photographing natural history objects in a horizontal position,
IE.—A method of demonstrating the thoracic duct in animals, id.—The
:ular ligaments of the head of the ribs in the cat, id.
' form of unpolarizable electrodes for physiological research, H. P.
I.
essful moth-trap, W. S. BARNARD.
and defective vision, D. G. CROLY.
.ew or little known anatomical and physiological instruments and appar-
. WILDER.—Notes on the anatomy of the cat's brain, id.—On a cat's
n the *corpus callosum* absent, id.
ıteresting insect habits and their development, W. S. BARNARD.
aın forms of Muscæ Volitantes, J. W. OSBORNE.
Triassic rocks of New Jersey, G. H. COOK.
een Mountain anticlinal, C. H. HITCHCOCK.
geology of Bermuda, W. NORTH RICE.
ological action of the Acid of Humus: I. On unconsolidated deposits.
lid rocks, A. A. JULIEN.
nesis of the Serpentine of Reichenstein, etc., R. B. HARE.
surface limits of thickness of the continental glacier, in New Jersey, J.

IV. *Anthropology.*

ınical influences of physical geography, D. WILSON.
ılogical notes from Japan, E. S. MORSE.
ıtion of a polished stone implement found in Monkton, Vt., J. M. CURRIER.
ostances amber and jade, illustrated by remarkable specimens, Mrs. E. A.

explanation of hereditary transmission, LOUIS ELSBERG.

The Ethnology of the islands of the Indian and Pacific oceans; illustrated by a large colored map, A. S. BICKMORE.

The sign language of the North American Indians, GARRICK MALLERY.

On some large and remarkable stone implements of the southern mound builders, F. W. PUTNAM.—On the pottery of the southern mound builders, id.

Superstitions among the ancient inhabitants of the Mississippi valley relative to the owl, to the rabbit, to serpents, to thunder, J. G. HENDERSON.—Lake Erie and the Eries, id.

Exhibition of archæological objects, S. S. HALDEMAN.

Archæology of Champlain valley, giving a general account of recent discoveries, G. H. PERKINS.

Consonantal expression of emotion, C. J. BLAKE.

2. *British Association.*—The meeting of the British Association—the forty-ninth—was held at Sheffield during the week from August 20th to August 28th. The exercises were opened on Wednesday evening, the 20th, by the Inaugural Address of the President, Professor G. J. Allman; devoted to "an account of the most generalized expression of living matter, and of the more recent investigations into its nature and phenomena." The attendance was not very large, but the papers were numerous and excited much interest; on the whole the meeting is described as having been one of decided success. The first of the evening discourses was delivered by Mr. W. Crookes upon Radiant Matter. It was illustrated by a large number of remarkably beautiful and brilliant experiments, performed on so large a scale that they were visible to an audience of nearly two thousand persons—this lecture forms the opening article in the present number of this Journal. The next meeting of the Association is to be held at Swansea, with Professor A. R. Ramsay as President. The meeting of the following year, 1881, is appointed for York.

3. *A Treatise on Hygiene and Public Health:* edited by ALBERT H. BUCK, M.D. 2 vols. 8vo. pp. 792, 657. New York, 1879. (William Wood & Co.)—This treatise consists of a series of twenty-five essays specially prepared by nearly as many contributors, most of whom are already known as specialists in various departments of sanitary science, medicine or surgery, or who are officers of boards of health. The essays treat of such special subjects as Infant Hygiene, Foods and Drinks, Food Adulterations, Water and Water Supply, Ventilation, Drainage and Sewerage in their sanitary aspects, the Hygiene of occupations, of camps and of marine service, Hospital Construction, Public Health, Vital Statistics, Public Nuisances, Disinfectants, Quarantine, etc., suitably edited and arranged.

As would be inferred the essays are of different degrees of excellence and completeness, and the treatise in a measure combines the characters of a hand-book of hygiene and a cyclopedia of sanitary science. As a whole, the work is well done. Some of the papers are particularly good; several of them are supplemented with a bibliography of the subject, and most of them are adapted to popular as well as professional readers. The treatise is a valuable contribution to sanitary literature in that it is a presentation of the subjects in the light of our present knowledge, by recognized authorities. W. H. B.

THE

AMERICAN

JOURNAL OF SCIENCE AND ARTS.

[THIRD SERIES.]

[Correction, by the Author, for the table on page 393.]

Results of Observations.

Each number is the mean of ten observations.

299830	299940	299860	299870	299870
299720	299920	299860	299790	299820
299880	299940	299860	299790	299760
300050	299920	299840	299800	299790
299910	299860	299700	299780	299740
299830	299780	299700	299750	299790
299930	299830	299600	299740	299770
299960	299860	299840	299720	299790
299960	299880	299950	299730	299920
299860	299820	299930	299740	299950
299980	299810	299860	299890	299970
299960	299770	299890	299900	299970
299910	299790	299830	299870	299790
299630	299860	299850	299840	299720
299740	299860	299820	299860	299890
299790	299810	299820	299700	299920
299980	299780	299830	299820	299930
299980	299770	299820	299830	299780
299940	299740	299820	299830	299790
299940	299780	299820	299760	299850

Mean	=299838	
Cor. for temp.	= +12	(of steel tape, etc.)
Vel. of light in air	=299850	
Cor. for vacuo	= +80	
Vel. of light in vacuo	=299930	

In the short time now at my command, I can only attempt to present a rapid sketch of the principal steps in the progress of this science. The literature of the subject, especially in connection with the discussions it provoked, is voluminous, and an outline of the history itself must suffice for my present purpose.

In looking over the records of Palæontology, its history may conveniently be divided into four periods, well marked by prominent features, but, like all stages of intellectual growth, without definite boundaries.

The first period, dating back to the time when men first noticed fossil remains in the rocks, and queried as to their nature, is of special historic interest. The most prominent characteristic of this period was, a long and bitter contest as to the *nature of fossil remains*. Were they mere "sports of Nature," or had they once been endowed with life? Simple as this problem now seems, centuries passed before the wise men of that time were agreed upon its solution.

Sea shells in the solid rock on the tops of mountains early attracted the attention of the ancients, and the learned men among them seem to have appreciated in some instances their true character, and given rational explanations of their presence.

The philosopher Zenophanes, of Colophon, who lived about 500 B. C., mentions the remains of fishes and other animals in the stone quarries near Syracuse; the impression of an anchovy in the rock of Paros, and various marine fossils at other places. His conclusion from these facts was, that the surface of the earth had once been in a soft condition at the bottom of the sea; and thus the objects mentioned were entombed. Herodotus, half a century later, speaks of marine shells on the hills of Egypt, and over the Libyan desert, and he inferred therefrom that the sea had once covered that whole region. Empedocles, of Agrigentum (450 B. C.), believed that the many hippopotamus bones found in Sicily were remains of human giants, in comparison with which the present race were as children. Here, he thought, was a battle field between the gods and the Titans, and the bones belonged to the slain. Pythagoras (582 B. C.) had already anticipated one conclusion of modern geology, if the following statement, attributed to him by Ovid, was his own :*

Vidi ego quod fuerat solidissima tellus,
Esse fretum: vidi factas ex æquore terras;
Et procul a pelago conchæ jacuere marinæ.

* Metamorphoses, Liber XV, 262.

Aristotle (384–322 B. C.) was not only aware of the existence of fossils in the rocks, but has also placed on record sagacious views as to the changes in the earth's surface necessary to account for them. In the second book of his Meteorics, he says: "The changes of the earth are so slow in comparison to the duration of our lives, that they are overlooked; and the migrations of people after great catastrophes and their removal to other regions, cause the event to be forgotten." Again, in the same work, he says: "As time never fails, and the universe is eternal, neither the Tanais, nor the Nile, can have flowed for ever. The places where they rise were once dry, and there is a limit to their operations: but there is none to time. So of all other rivers; they spring up, and they perish; and the sea also continually deserts some lands and invades others. The same tracts, therefore, of the earth are not, some always sea, and others always continents, but everything changes in the course of time."

Aristotle's views on the subject of spontaneous generation were less sound, and his doctrines on this subject exerted a powerful influence for the succeeding twenty centuries. In the long discussion that followed concerning the nature of fossil remains, Aristotle's views were paramount. He believed that animals could originate from moist earth or the slime of rivers, and this seemed to the people of that period a much simpler way of accounting for the remains of animals in the rocks than the marvelous changes of sea and land otherwise required to explain their presence. Aristotle's opinion was in accordance with the Biblical account of the creation of Man out of the dust of the earth, and hence more readily obtained credence.

Theophrastus, a pupil of Aristotle, alludes to fossil fishes found near Heraclea, in Pontus, and in Paphlagonia, and says: "They were either developed from fish spawn left behind in the earth, or gone astray from rivers or the sea into cavities of the earth, where they had become petrified." In treating of fossil ivory and bones, the same writer supposed them to be produced by a certain plastic virtue latent in the earth. To this same cause, as we shall see, many later authors attributed the origin of all fossil remains.

Previous to this, Anaximander, the Miletian philosopher, who was born about 610 years before Christ, had expressed essentially the same view. According to both Plutarch and Censorinus, Anaximander taught that fishes, or animals very like fishes, sprang from heated water and earth, and from these animals came the human race; a statement which can hardly be considered as anticipating the modern idea of evolution, as some authors have imagined.

The Romans added but little to the knowledge possessed by the Greeks in regard to fossil remains. Pliny (23–79 A. D), however, seems to have examined such objects with interest, and in his renowned work on Natural History gave names to several forms. He doubtless borrowed largely from Theophrastus, who wrote about three hundred years before. Among the objects named by Pliny were, "*Bucardia*, like to an ox's heart;" "*Brontia*, resembling the head of a tortoise, supposed to fall in thunder storms;" "*Glossoptra*, similar to a human tongue, which does not grow in the earth, but falls from heaven while the moon is eclipsed;" "the *Horn of Ammon*, possessing, with a golden color, the figure of a ram's horn;" *Ceraunia* and *Ombria*, supposed to be thunderbolts; *Ostracites*, resembling the oyster shell; *Spongites*, having the form of sponge; *Phycites*, similar to sea-weed or rushes. He also mentions stones resembling the teeth of hippopotamus; and says that Theophrastus speaks of fossil ivory, both black and white, of bones born in the earth, and of stones bearing the figure of bones.

Tertullian (160 A. D.) mentions instances of the remains of sea animals on the mountains, far from the sea, but uses them as a proof of the general deluge recorded in Scripture.

During the next thirteen or fourteen centuries, fossil remains of animals and plants seemed to have attracted so little attention, that few references are made to them by the writers of this period. During these ages of darkness, all departments of knowledge suffered alike, and feeble repetitions of ideas derived from the ancients seem to have been about the only contributions of that period to Natural Science.

Albert the Great (1205–1280 A. D.), the most learned man of his time, mentions that a branch of a tree was found, on which was a bird's nest containing birds, the whole being solid stone. He accounted for this strange phenomenon by the *vis formativa* of Aristotle, an occult force, which, according to the prevalent notions of the time, was capable of forming most of the extraordinary objects discovered in the earth.

Alexander *ab Alexandro*, of Naples, states that he saw, in the mountains of Calabria, a considerable distance from the sea, a variegated hard marble, in which many sea shells but little changed were heaped, forming one mass with the marble.

With the beginning of the sixteenth century, a great impetus was given to the investigation of organic fossils, especially in Italy, where this study really began. The discovery of fossil shells, which abound in this region, now attracted great attention, and a fierce discussion soon arose as to the true nature of these and other remains. The ideas of Aristotle in regard to

pontaneous generation, and especially his view of the hidden orces of the earth, which he claimed had power to produce uch remains, now for the first time were seriously quesioned, although it was not till nearly two centuries later that hese doctrines lost their dominant influence.

Leonardo da Vinci, the renowned painter and philosopher, who was born in 1452, strongly opposed the commonly accepted opinions as to the origin of organized fossils. He claimed that he fossil shells under discussion were what they seemed, and ıad once lived at the bottom of the sea. "You tell me," he ays, "that Nature and the influence of the stars have formed hese shells in the mountains; then show me a place in the nountains where the stars at the present day make shelly forms of different ages, and of different species in the same place." Again, he says, "In what manner can such a cause account or the petrifactions in the same place of various leaves, seaweeds, and marine crabs?"

In 1517, excavations in the vicinity of Verona brought to ight many curious petrifactions, which led to much speculation as to their nature and origin. Among the various authors who wrote on this subject was Fracastoro, who declared hat the fossils once belonged to living animals, which had ived and multiplied where found. He ridiculed the prevailing deas that the plastic force of the ancients could fashion stones nto organic forms. Some writers claimed that these shells ıad been left by Noah's flood, but to this idea Fracastoro offered a mass of evidence, which would now seem conclusive, out which then only aroused bitter hostility. That inundation, ıe said, was too transient; it consisted mainly of fresh water; and if it had transported shells to great distances, must have scattered them over the surface, not buried them in the nterior of mountains.

Conrad Gesner (1516–1565), whose history of animals has been considered the basis of modern zoology, published at Zurich in 1565 a small but important work entitled "*De omni rerum fossilium genere.*" It contained a catalogue of the collection of fossils made by John Kentmann. This is the oldest catalogue of fossils with which I am acquainted.

George Agricola (1494–1555) was, according to Cuvier, the irst mineralogist who appeared after the revival of learning in Europe. In his great work, "*De Re Metallica,*" published in 1546, he mentions various fossil remains, and says they were produced by a certain "*materia pinguis,*" or fatty matter, set n fermentation by heat. Some years later, Bauhin published a descriptive catalogue of the fossils he had collected in the ıeighborhood of Boll, in Wurtemberg.*

* *Historia novi et admirabilis Fontis Balneique Bollensis, in Ducatu Wirtembergico. Montbéliard,* 1598.

Andrew Mattioli, a distinguished botanist, adopted Agricola's notion as to the origin of organized fossils, but admitted that shells and bones might be turned into stone by being permeated by a "lapidifying juice." Falloppio, the eminent professor of anatomy at Padua, believed that fossil shells were generated by fermentation where they were found; and that the tusks of elephants, dug up near Apulia, were merely earthy concretions. Mercati, in 1574, published figures of the fossil shells preserved in the Museum of the Vatican, but expressed the opinion that they were only stones, that owed their peculiar shapes to the heavenly bodies. Olivi, of Cremona, described the fossils in the Museum at Verona, and considered them all "sports of nature."

Palissy, a French author, in 1580, opposed these views, and is said to have been the first to assert in Paris that fossil shells and fishes had once belonged to marine animals. Fabio Colonna appears to have first pointed out that some of the fossil shells found in Italy were marine, and some terrestrial.

Another peculiar theory discussed in the sixteenth century deserves mention. This was the vegetation theory, especially advocated by Tournefort and Camerarius, both eminent as botanists. These writers believed that the seeds of minerals and fossils were diffused throughout the sea and the earth, and were developed into their peculiar forms by the regular increment of their particles, similar to the formation of crystals. "How could the *Cornu Ammonis*," Tournefort asked, "which is constantly in the figure of a volute, be formed without a seed containing the same structure in the small, as in the larger forms? Who moulded it so artfully, and where are the moulds?" The stalactites which formed in caverns in various parts of the world were also supposed to be proofs of this vegetative growth.

Still another theory has been held at various times, and is not yet entirely forgotten, namely: that the Creator made fossil animals and plants just as they are found in the rocks, in pursuance of a plan beyond our comprehension. This theory has never prevailed among those familiar with scientific facts, and hence needs here no further consideration.

An interest in fossil remains arose in England later than on the continent; but when attention was directed to them, the first opinions as to their origin were not less fanciful and erroneous than those to which we have already referred. Dr. Plot, in his "Natural History of Oxfordshire," published in 1677, considered the origin of fossil shells and fishes to be due to a "plastic virtue, latent in the earth," as Theophrastus had suggested long before. Lhwyd, in his "*Lithophylacii Britannici Ichnographia*," published at Oxford in 1699, gives a cata-

ogue of English fossils contained in the Ashmolean Museum. Ie opposed the *vis plastica* theory, and expressed the opinion hat the spawn of fishes and other marine animals had been aised with the vapors from the sea, conveyed inland by clouds, nd deposited by rain, had permeated into the interior of the arth, and thus produced the fossil remains we find in the ocks. About this time several important works were pubished in England by Dr. Martin Lister, which did much to nfuse a true knowledge of fossil remains. He gave figures f recent shells side by side with some of the fossil forms, so hat the resemblance became at once apparent. The fossil pecies of shells he called "turbinated and bivalve stones," nd adds, "either these were terriginous, or, if otherwise, the nimals which they so exactly represent have become extinct."

During the seventeenth century there was a considerable dvance in the study of fossil remains. The discussions in egard to the nature and origin of these objects, had called ttention to them, and many collections were now made, espeially in Italy, and also in Germany, where a strong interest n this subject had been aroused. Catalogues of these collecions were not unfrequently published, and some of them were llustrated with such accurate figures, that many of the species an now be readily recognized. In this century, too, an mportant step in advance was made by the collection and lescription of fossils from particular localities and regions, in listinction from general collections of curiosities.

Casper Schwenkfeld, in 1600, published a catalogue of the ossils discovered in Silesia; in 1622, a detailed description of he renowned Museum of Calceolarius, of Verona, appeared; nd in 1642, a catalogue of Besler's collection. Wormius's cataogue was published in 1652; Spener's in 1663; and Septala's n 1666. A description of the Museum of the King of Denark was issued in 1669; Cottorp's catalogue in 1674; and that f the renowned Kirscher in 1678. Dr. Grew gave an account n 1687 of the specimens in the Museum of Gresham's College n England; and in 1695, Petiver of London published a cataogue of his very extensive collection. A catalogue by Fred. auchmund, on the fossils of Hildeshein, appeared in 1669, nd the fossils of Switzerland were described by John Jacob Vagner in 1689. Among similar works, were the dissertations f Gyer, at Frankfort, and Albertus, at Leipsic.

Steno, a Dane, who had been professor of anatomy at Padua, ublished, in 1669, one of the most important works of this eriod.* He entered earnestly into the controversy as to the rigin of fossil remains, and by dissecting a shark from the

* *De solido intra solidum naturaliter contento.*

Mediterranean, proved that its teeth were identical with some found fossil in Tuscany. He also compared the fossil shells found in Italy with existing species, and pointed out their resemblance. In the same work, Steno expressed some very important views in regard to the different kinds of strata, and their origin, and first placed on record the important fact that the oldest rocks contain no fossils.

Scilla, the Sicilian painter, published in 1670 a work on the fossils of Calabria, well illustrated. He is very severe against those who doubted the organic origin of fossils, but is inclined to consider them relics of the Mosaic deluge.

Another instance of the power of the *lusus naturæ* theory, even at the close of the seventeenth century, deserves mention. In the year 1696, the skeleton of a fossil elephant was dug up at Tonna, near Gotha, in Germany, and was described by William Ernest Tentzel, a teacher in the Gotha Gymnasium. He declared the bones to be the remains of an animal that had lived long before. The Medical Faculty in Gotha, however, considered the subject, and decided officially that this specimen was only a freak of nature.

Beside the authors I have mentioned, there were many others who wrote about fossil remains before the close of the seventeenth century, and took part in the general discussion as to their nature and origin. During the progress of this controversy the most fantastic theories were broached and stoutly defended, and although refuted from time to time by a few clear-headed men, continually sprang up anew, in the same or modified forms. The influence of Aristotle's views of equivocal generation, and especially the scholastic tendency to disputation, so prevalent during the middle ages, had contributed largely to the retardation of progress, and yet a real advance in knowledge had been made. The long contest in regard to the nature of fossil remains was essentially over, for the more intelligent opinion at the time now acknowledged that these objects were not mere "sports of nature," but had once been endowed with life. At this point, therefore, the first period in the history of Palæontology, as I have indicated it, may appropriately end.

It is true that later still, the old exploded errors about the plastic force and fermentation were from time to time revived, as they have been almost to the present day; but learned men, with few exceptions, no longer seriously questioned that fossils were real organisms, as the ancients had once believed. The many collections of fossils that had been brought together, and the illustrated works that had been published about them, were a foundation for greater progress, and, with the eighteenth century, the second period in the history of Palæontology began.

The main characteristic of this period was the general belief, that *fossil remains were deposited by the Mosaic deluge.* We have seen that this view had already been advanced, but it was not till the beginning of the eighteenth century that it became the prevailing view. This doctrine was strongly opposed by some courageous men, and the discussion on the subject soon became even more bitter than the previous one, as to the nature of fossils.

In this diluvial discussion theologians and laymen alike took part. For nearly a century the former had it all their own way, for the general public, then as now, believed what they were taught. Noah's flood was thought to have been universal, and was the only general catastrophe of which the people of that day had any knowledge or conception.

The scholars among them were of course familiar with the accounts of Deucalion and his ark, in a previous deluge, as we are to-day with similar traditions held by various races of men. The firm belief that the earth and all it contains was created in six days; that all life on the globe was destroyed by the deluge, except alone what Noah saved; and that the earth and its inhabitants were to be destroyed by fire, was the foundation on which all knowledge of the earth was based. With such fixed opinions, the fossil remains of animals and plants were naturally regarded as relics left by the flood described in Holy Writ. The dominant nature of this belief is seen in nearly all the literature in regard to fossils published at this time, and some of the works which then appeared have become famous on this account.

In 1710, David Büttner published a volume entitled "*Rudera Diluvii Testes.*" He strongly opposed Lhwyd's explanation of the origin of fossils, and referred these objects directly to the Flood. The most renowned work, however, of this time, was published at Zurich, in 1726, by Scheuchzer, a physician and naturalist, and professor in the University of Altorf. It bore the title "*Homo Diluvii Testis.*" The specimen upon which this work was based was found at Oeningen, and was regarded as the skeleton of a child destroyed by the Deluge. The author recognized in this remarkable fossil, not merely the skeleton, but also portions of the muscles, the liver, and the brain. The same author was fortunate enough to discover, subsequently, near Altorf, two fossil vertebræ, which he at once referred to that "Accursed race destroyed by the Flood!" These, also, he carefully described and figured in his "*Physica Sacra,*" published at Ulm in 1731. Engravings of both were subsequently given in the "Copper-Bible." Cuvier afterward examined these interesting relics, and pronounced the skeleton of the supposed child to be the remains of a gigantic

Salamander, and the two vertebræ to be those of an Ichthyosaurus!

Another famous book appeared in Germany in the same year in which Scheuchzer's first volume was published. The author was John Bartholomew Adam Beringer, professor at the University of Würtzburg, and his great work* indirectly had an important influence upon the investigation of fossil remains. The history of the work is instructive, if only as an indication of the state of knowledge at that date. Professor Beringer, in accordance with views of his time, had taught his pupils that fossil remains, or "figured stones," as they were called, were mere "sports of nature." Some of his fun-loving students reasoned among themselves, "If Nature can make figured stones in sport, why cannot we?" Accordingly, from the soft limestone in the neighboring hills, they carved out figures of marvelous and fantastic forms, and buried them at the localities where the learned Professor was accustomed to dig for his fossil treasures. His delight at the discovery of these strange forms encouraged further production, and taxed the ingenuity of these youthful imitators of Nature's secret processes. At last Beringer had a large and unique collection of forms, new to him, and to science, which he determined to publish to the world. After long and patient study, his work appeared, in Latin, dedicated to the reigning prince of the country, and illustrated with twenty-one folio plates. Soon after the book was published, the deception practiced upon the credulous Professor became known; and, in place of the glory he expected from his great undertaking, he received only ridicule and disgrace. He at once endeavored to repurchase and destroy the volumes already issued, and succeeded so far that few copies of the first edition remain. His small fortune, which had been seriously impaired in bringing out his grand work, was exhausted in the effort to regain what was already issued, as the price rapidly advanced in proportion as fewer copies remained; and, mortified at the failure of his life's work, he died in poverty. It is said that some of his family, dissatisfied with the misfortune brought upon them by this disgrace and the loss of their patrimony, used a remaining copy for the production of a second edition, which met with a large sale, sufficient to repair the previous loss, and restore the family fortune. This work of Beringer, in the end, exerted an excellent influence upon the dawning science of fossil remains. Observers became more cautious in announcing supposed discoveries, and careful study of natural objects gradually replaced vague hypotheses.

* *Lithographia Wirceburgensis, ducentis lapidum figuratorum, a potiori, insectiformium, prodigiosis imaginibus exornata.* Wirceburgi, 1726. Edit. II. Francofurti et Lipsiae. 1767.

The above works, however, are hardly fair examples of the literature on fossils during this part of the eighteenth century. Scheuchzer had previously published his well-known "Complaint and Vindication of the Fishes," illustrated with good plates. Moro, in his work on "Marine Bodies which are found in the Mountains," 1740, showed the effects of volcanic action in elevating strata, and causing faults. Vallisneri had studied with care the marine deposits of Italy. Donati, in 1750, had investigated the Adriatic, and ascertained by soundings that shells and corals were being imbedded in the deposits there, just as they were found in the rocks.

John Gesner's dissertation, "*De Petrificatis,*" published at Leyden in 1758, was a valuable contribution to the science. He enumerated the various kinds of fossils, and the different conditions in which they are found petrified, and stated that some of them, like those at Oeningen, resembled the shells, fishes, and plants of the neighboring region, while others, such as Ammonites and Belemnites, were either unknown species, or those found only in distant seas. He discusses the structure of the earth at length, and speculates as to the causes of changes in sea and land. He estimates that, at the observed rate of recession of the ocean, to allow the Appenines, whose summits are filled with marine shells, to reach their present height, would have taken about eighty thousand years, a period more than "ten times greater than the age of the universe." He accordingly refers the change to the direct command of the Deity, as related by Moses, that, "The waters should be gathered together in one place, and the dry land appear."

Voltaire (1694–1778), discussed geological questions and the nature of fossils in several of his works, but his published opinions are far from consistent. He ridiculed effectively and justly the cosmogonists of his day, and showed, also, that he knew the true nature of organic remains. Finding, however, that theologians used these objects to confirm the Scriptural account of the deluge, he changed his views, and accounted for fossil shells found in the Alps, by suggesting that they were Eastern species, dropped by the pilgrims on their return from the Holy Land!

Buffon, in 1749, published his important work on Natural History, and included in it his "Theory of the Earth," in which he discussed, with much ability, many points in Geology. Soon after the book was published, he received an official letter from the Faculty of Theology in Paris, stating that fourteen propositions in his works were reprehensible, and contrary to the creed of the church. The first objectionable proposition was as follows: "The waters of the sea have produced the mountains and valleys of the land,—the waters of the heavens

reducing all to a level, will at last deliver the whole land over to the sea, and the sea successively prevailing over the land, will leave dry new continents like those we inhabit."

Buffon was politely requested by the college to recant, and having no particular desire to be a martyr to science, submitted the following declaration, which he was required to publish in his next work: "I declare that I had no intention to contradict the text of Scripture; that I believe most firmly all therein related about the creation, both as to order of time and matter of fact; and I abandon everything in my book respecting the formation of the earth, and, generally, all which may be contrary to the narration of Moses."

This single instance will suffice to indicate one great obstacle to the advancement of science, even up to the middle of the eighteenth century.

Another important work appeared in France about this time, Bourguet's "*Traité des Pétrifactions*," published in 1758, which is well illustrated with faithful plates. In England, a discourse on earthquakes, by Dr. Robert Hooke, was published in 1705. This author held some views in advance of his time, and maintained that figured stones were "really the several bodies they represent or the moldings of them petrified, and not, as some have imagined, a *lusus naturæ*, sporting herself in the needless formation of useless things." He anticipates one important conclusion from fossils, when he states that "though it must be very difficult to read them and to raise a chronology out of them, and to state the intervals of time wherein such or such catastrophes and mutations have happened, yet it is not impossible." He also states that fossil turtles, and such large Ammonites as are found in Portland, seem to have been the productions of hotter countries, and hence it is necessary to suppose that England once lay under the sea within the torrid zone. He seems to have suspected that some of the fossils of England belonged to extinct species, but thought they might possibly be found living in the bottom of distant oceans.

Dr. Woodward's "Natural History of the Fossils of England" appeared in 1729. This work was based on a systematic collection of fossils which he had brought together, and which he subsequently bequeathed to the University of Cambridge, where it is still preserved, with his arrangement carefully retained. This descriptive part of this work is interesting, but his conclusions are made to coincide strictly with the Scriptural account of the creation and deluge. He had previously stated, in another work, that he believed, "the whole terrestrial globe to have been taken to pieces and dissolved at the flood, and the strata to have settled down from this promiscuous mass." In support of this view, he stated that, "Marine bodies are lodged

in the strata according to the order of their gravity, the heavier shells in stones, the lighter in chalk, and so of the rest."*

The most important work on fossils published in Germany at this time, was that of George Wolfgang Knorr, which was continued after his death by Walch. This work consisted of four folio volumes, with many plates, and was printed at Nuremberg, 1755–73. A large number of fossils were accurately figured and described, and the work is one of permanent value.† A French translation of this work appeared in 1767–78. Burton's "*Oryctographie de Bruxelles*," 1784, contains figures and descriptions of fossils found in Belgium.

Abraham Gottlieb Werner (1750–1817), Professor of Mineralogy at Freyberg, did much to advance the science of Geology, and indirectly, that of fossils. He first indicated the relations of the main formations to each other, and, according to his pupil, Professor Jameson, first made the highly important observation "that different formations can be discriminated by the petrifactions they contain." Moreover, "that the petrifactions contained in the oldest rocks are very different from any of the species of the present time; that the newer the formation, the more do the remains approach in form to the organic beings of the present creation." Unfortunately, Werner published little, and his doctrines were mainly disseminated by his enthusiastic pupils.

The great contest between the Vulcanists and the Neptunists started at this time, mainly through Werner, whose doctrines led to the controversy. The comparative merits of fire and water, as agencies in the formation of certain rocks, were discussed with a heat and acrimony characteristic of the subject and the time. Werner believed in the aqueous theory, while the igneous theory was especially advocated by Hutton of Edinburgh, and his illustrator, Playfair. This discussion resulted in the advancement of descriptive geology, but the study of fossils gained little thereby.

The "*Protogæa*" of Leibnitz, the great mathematician, published in 1749, about thirty years after his death, was a work of much merit. This author supposed that the earth had gradually cooled from a state of igneous fusion, and was subsequently covered with water. The subsidence of the lower part of the earth, the deposits of sedimentary strata from inundations, and their induration, as well as other changes, followed. All this, he supposed to have been accomplished in a period of six natural days. In the same work Leibnitz shows that he had examined fossils with considerable care.

* Essay towards a Natural History of the Earth. 1695.

† *Lapides ex celeberr. viror. sententia diluvii universalis testes, quos in ordines ac species distribuit, suis coloribus expremit, etc.* 272 Tab. 1755–73.

Linnæus (1707–1778), the famous Swedish botanist, and the founder of the modern system of nomenclature in Natural History, confined his attention almost entirely to the living forms. Although he was familiar with the literature of fossil remains, and had collected them himself, he did not include them in his system of plants and animals, but kept them separate, with the minerals; hence he did little directly to advance this branch of science.

During the last quarter of the eighteenth century, the belief that fossil remains were deposited by the Deluge sensibly declined, and the dawn of a new era gradually appeared. Let us pause for a moment here, and see what real progress had been made; what foundation had been laid on which to establish a science of fossil remains.

The true nature of these objects had now been clearly determined. They were the remains of animals and plants. Most of them certainly were not the relics of the Mosaic Deluge, but had been deposited long before, part in fresh water and part in the sea. Some indicated a mild climate, and some the tropics. That any of these were extinct species, was as yet only suspected. Large collections of fossils had now been made, and valuable catalogues, well illustrated, had been published. Something was known, too, of the geological position of fossils. Steno, long before, had observed that the lowest rocks were without life. Lehmann had shown that above these primitive rocks, and derived from them, were the secondary strata, full of the records of life; and above these were alluvial deposits, which he referred to local floods, and the Deluge of Noah. Rouelle, Fuchsel, and Odoardi had shed new light on this subject. Werner had distinguished the transition rocks, containing fossil remains, between the primitive and the secondary, while everything above the chalk he grouped together, as the "overflowed land." Werner, as we have seen, had done more than this, if we give him the credit his pupils claim for him. He had found that the formations he examined contained each its own peculiar fossils, and that from the older to the newer there was a gradual approach to recent forms. William Smith had worked out the same thing in England, and should equally divide the honor of this important discovery.

The greatest advance, however, up to this time, was that men now preferred to *observe*, rather than to *believe*, and facts were held in greater esteem than vague speculations. With this preparation for future progress, the second period in the history of Palæontology, as I have divided it, may appropriately be considered at an end.

Thus far, I have said nothing in regard to one branch of my subject, the *methods* of Palæontological research, for up to

s time, of method there was none. We have seen that those the ancients who noticed marine shells in the solid rock, led them such, and concluded that they had been left there the sea. The discovery of fossils led directly to theories of w the earth was formed. Here the progress was slow. bterranean spirits were supposed to guard faithfully the 'steries of the earth; while above the earth, Authority arded with still greater power the secrets men in advance their age sought to know. The dominant idea of the first teen centuries of the present era was, that the universe s made for Man. This was the great obstacle to the correct ;ermination of the position of the earth in the universe, and, er, of the age of the earth. The contest of Astronomy iinst authority was long and severe, but the victory was at t with science. The contest of Geology against the same wer followed, and continued almost to our day. The result still the same. In the early stages of this contest, there was strife, for science was benumbed by the embrace of super- ;ion and creed, and little could be done till that was cast off. a superstitious age, when every natural event is referred to supernatural cause, science cannot live; and often as the red fire may be kindled by courageous far-seeing souls, will be quenched by the dense mists of ignorance around it. ircely less fatal to the growth of science is the age of ithority, as the past proves too well. With freedom of ought, came definite knowledge, and certain progress;—but ɔ thousand years was long to wait.

With the opening of the present century, began a new era Palæontology, which we may here distinguish as the third 'iod in its history. This branch of knowledge became now science. Method replaced disorder, and systematic study perseded casual observation. For the next half century the rance was continuous, and rapid. One characteristic of this 'iod was, *the accurate determination of fossils by compar- n with living forms.* This will separate it from the two mer epochs. Another distinctive feature of this period was general belief that, *every species, recent and extinct, was eparate creation.*

At the very beginning of the epoch we are now to consider, ee names stand out in bold relief: Cuvier, Lamarck, and lliam Smith. To these men, the science of palæontology es its origin. Cuvier and Lamarck, in France, had all the wer which great talent, education, and station could give; lliam Smith, an English surveyor, was without culture or uence. The last years of the eighteenth century had been nt by each of these men in preparation for his chosen

work, and the results were now given to the world. Cuvier laid the foundation of the palæontology of Vertebrate animals; Lamarck, of the Invertebrates; and Smith established the principles of Stratigraphical Palæontology. The investigator of fossils to-day seldom needs to consult earlier authors of the science.

George Cuvier (1769–1832), the most famous naturalist of his time, was led to the study of extinct animals by ascertaining that the remains of fossil elephants he examined were extinct species. "This idea," he says later, "which I announced to the Institute in the month of January 1796, opened to me views entirely new respecting the theory of the earth, and determined me to devote myself to the long researches and to the assiduous labors which have now occupied me for twenty-five years."*

It is interesting to note here that in this first investigation of fossil vertebrates, Cuvier employed the same method that gave him such important results in his later researches. Remains of elephants had been known to Europe for centuries, and many authors, from Pliny down to the contemporaries of Cuvier, had written about them. Some had regarded the bones as those of human giants, and those who recognized what they were considered them remains of the elephants imported by Hannibal or the Romans. Cuvier, however, compared the fossils directly with the bones of existing elephants, and proved them to be distinct. The fact that these remains belonged to extinct species was of great importance. In the case of fossil shells, it was difficult to say that any particular form was not living in a distant ocean; but the two species of existing elephants, the Indian and the African, were well known, and there was hardly a possibility that another living one would be found.

It is important to bear in mind, too, that Cuvier's preparation for the study of the remains of animals was far in advance of any of his predecessors. He had devoted himself for years to careful dissections in the various classes of the animal kingdom, and was really the founder of comparative anatomy, as we now understand it. Cuvier investigated the different groups of the whole kingdom with care, and proposed a new classification founded on the plan of structure, which in its main features is the one in use to-day. The first volume of his Comparative Anatomy appeared in 1800, and the work was completed in five volumes in 1805.

Previous to Cuvier, the only general catalogue of animals was contained in Linnæus' "*Systema Naturæ.*" In this work, as we have seen, fossil remains were placed with the Minerals, not in their appropriate places among the animals and plants.

* *Ossemens Fossiles*, Second Edition, Vol. I, p. 178.

Cuvier enriched the animal kingdom by the introduction of fossil forms among the living, bringing all together into one comprehensive system. His great work, "*Le Règne Animal,*" appeared in four volumes, in 1817, and with its two subsequent editions remains the foundation of modern zoology. Cuvier's classic work on vertebrate fossils—"*Recherches sur les Ossemens Fossiles,*" in four volumes, appeared in 1812–13. Of this work, it is but just to say that it could only have been written by a man of genius, profound knowledge, the greatest industry, and with the most favorable opportunities.

The introduction to this work was the famous "Discourse on the Revolutions of the Surface of the Globe," which has perhaps been as widely read as any other scientific essay. The discovery of fossil bones in the gypsum quarries of Paris, by the workmen, who considered them human remains; the careful study of these relics by Cuvier, and his restorations from them of strange beasts that had lived long before, is a story with which you are all familiar. Cuvier was the first to prove that the earth had been inhabited by a succession of different series of animals, and he believed that those of each period were peculiar to the age in which they lived.

In looking over his work after a lapse of three-quarters of a century, we can now see that Cuvier was wrong on some important points, and failed to realize the direction in which science was rapidly tending. With all his knowledge of the earth, he could not free himself from tradition, and believed in the universality and power of the Mosaic deluge. Again, he refused to admit the evidence brought forward by his distinguished colleagues against the permanence of species, and used all his great influence to crush out the doctrine of evolution, then first proposed. Cuvier's definition of a species, the dominant one for half a century, was as follows: "A species comprehends all the individuals which descend from each other, or from a common parentage, and those which resemble them as much as they do each other."

The law of "Correlation of Structures," as laid down by Cuvier, has been more widely accepted than almost any thing else that bears his name; and yet, although founded in truth, and useful within certain limits, it would certainly lead to serious error if applied widely in the way he proposed.

In his Discourse, he sums this law as follows: "A claw, a shoulder blade, a condyle, a leg or arm bone, or any other bone separately considered, enables us to discover the description of teeth to which they have belonged; so also reciprocally we may determine the form of the other bones from the teeth. Thus, commencing our investigation by a careful survey of any one bone by itself, a person who is sufficiently master of the

laws of organic structure, may, as it were, reconstruct the whole animal to which that bone had belonged."

We know to-day that unknown extinct animals cannot be restored from a single tooth or claw, unless they are very similar to forms already known. Had Cuvier, himself, applied his methods to many forms from the early Tertiary or older formations, he would have failed. If, for instance, he had had before him the disconnected fragments of an Eocene Tillodont, he would undoubtedly have referred a molar tooth to one of his Pachyderms; an incisor tooth to a Rodent; and a claw bone to a Carnivore. The tooth of a Hesperornis would have given him no possible hint of the rest of the skeleton, nor its swimming feet the slightest clue to the ostrich-like sternum or skull. And yet, the earnest belief in his own methods led Cuvier to some of his most important discoveries.

Jean Lamarck (1744–1829), the philosopher and naturalist, a colleague of Cuvier, was a learned botanist before he became a zoologist. His researches on the invertebrate fossils of the Paris Basin, although less striking, were not less important than those of Cuvier on the vertebrates; while the conclusions he derived from them form the basis of modern biology. Lamarck's method of investigation was the same, essentially, as that used by Cuvier, namely: a direct comparison of fossils with living forms. In this way, he soon ascertained that the fossil shells imbedded in the strata beneath Paris were, many of them, extinct species, and those of different strata differed from each other. His first memoir on this subject appeared in 1802,* and, with his later works, effected a revolution in conchology. His "System of Invertebrate Animals" appeared the year before, and his famous "*Philosophie Zoologique*," in 1809. In these two works, Lamarck first announced the principles of Evolution. In the first volume of his "Natural History of Invertebrate Animals,"† he gave his theory in detail; and to-day one can only read with astonishment his far-reaching anticipations of modern science. These views were strongly supported by Geoffroy Saint-Hilaire, but bitterly opposed by Cuvier; and their great contest on this subject is well known.

In looking back from this point of view, the philosophical breadth of Lamarck's conclusions, in comparison with those of Cuvier, is clearly evident. The invertebrates on which Lamarck worked offered less striking evidence of change than the various animals investigated by Cuvier; yet they led Lamarck directly to Evolution, while Cuvier ignored what was before him on this point, and rejected the proof offered

* *Mémoires sur les fossiles des environs de Paris.* 1802–6.

† *Histoire naturelle des animaux sans vertèbres.* 7 vols. Paris, 1815–1822. 2d edition. 11 vols. 1835–1845.

by others. Both pursued the same methods, and had an abundance of material on which to work, yet the facts observed induced Cuvier to believe in catastrophes; and Lamarck, in the uniform course of nature. Cuvier declared species to be permanent; Lamarck, that they were descended from others. Both men stand in the first rank in science; but Lamarck was the prophetic genius, half a century in advance of his time.

While the Paris Basin was yielding such important results for Palæontology, its geological structure was being worked out with great care. The results appeared in a volume by Cuvier and Alex. Brongniart, chiefly the work of the latter, published in 1808.* This was the first systematic investigation of Tertiary strata. Three years later, the work was issued in a more extended form. The separate formations were here carefully distinguished by their fossils, the true importance of which for this purpose being distinctly recognized. This advance was not accepted without some opposition, and it is an interesting fact that Jameson, who claimed for Werner the theory here put in practice, rejected its application, and wrote as follows: "To Cuvier and Brongniart we are indebted for much valuable information in their description of the country around Paris, but we must protest against the use they have made of fossil organic remains in their geognostical descriptions and investigations."†

William Smith (1769–1839), "the father of English Geology," had previously published a "Tabular View of the British Strata." He appears to have arrived independently at essentially the same view as Werner in regard to the relative position of stratified rocks. He had determined that the order of succession was constant, and that the different formations might be identified at distant points by the fossils they contained. In his later works, "Strata identified by Organized Fossils," published in 1816–20, and "Stratigraphical System of Organized Fossils," 1817, he gave to the world results of many years of careful investigations on the Secondary formations of England. In the latter work, he speaks of the success of his method in determining strata by their fossils, as follows: "My original method of tracing the strata by the organized fossils imbedded therein, is thus reduced to a science not difficult to learn. Ever since the first written account of this discovery was circulated in 1799, it has been closely investigated by my scientific acquaintances in the vicinity of Bath, some of whom search the quarries of different Strata in that district, with as much cer-

* *Essai sur la Géographie Mineralogique des environs de Paris.* 4to, 1808.
† Translation of Cuvier's Discourse. Note K. (B.), p. 103, 1817.

tainty of finding the characteristic Fossils of the respective rocks, as if they were on the shelves of their cabinets."

The systematic study of fossils now attracted attention in England, also, and was prosecuted with considerable zeal, although with less important results than in France. An extensive work on this subject, by James Parkinson, entitled "Organic Remains of a Former World," was begun in 1804, and completed in three volumes in 1811. A second edition appeared in 1833. This work was far in advance of previous publications in England, and, being well illustrated, did much to make the collection and study of fossils popular. The belief in the geological effects of the Deluge had not yet lost its power, although restricted now to the later deposits; for Parkinson in his later edition wrote as follows: "Why the earth was at first so constituted that the deluge should be rendered necessary—why the earth could not have been at first stored with all those substances, and endued with all those properties which seemed to have proceeded from the deluge—why so many beings were created, as it appears, for the purpose of being destroyed—are questions which I presume not to answer."

William Buckland (1784–1856), published in 1823 his celebrated "*Reliquiæ Diluvianæ*," in which he gave the results of his own observations in regard to the animal remains found in the caves, fissures and alluvial gravels of England. The facts presented are of great value, and the work was long a model for similar researches. Buckland's conclusions were, that none of the human remains discovered in the caves were as old as the extinct mammals found with them, and that the Deluge was universal. In speaking of fossil bones found in the Himalaya mountains, he says: "The occurrence of these bones at such an enormous elevation in the region of eternal snow, and consequently in a spot now unfrequented by such animals as the horse and deer, can, I think, be explained only by supposing them to be of antediluvian origin, and that the carcasses of the animals were drifted to their present place, and lodged in sand, by the diluvial waters."

The foundation of the "Geological Society of London," in 1807, marks an important point in the history of palæontology. To carefully collect materials for future generalizations, was the object in view, and this organization gradually became the centre in Great Britain for those interested in geological science. The society was incorporated in 1826, and has since been the leading organization in Europe for the advancement of the sciences within its field. The Geological Society of France, established at Paris in 1832, and the German Geological Society, founded at Berlin in 1848, have likewise contributed largely to geological investigations in these countries, and

some extent in other parts of the world. In the publications these three societies, the student of palæontology will find a ne of valuable materials for his work.

The systematic study of fossil Plants may be said to date m the publication of Adolphe Brongniart's "*Prodrome*," 1828.* This was very soon followed by his larger work, *Iistoire des végétaux fossiles*," issued in 1828–48. Brongrt pursued the same method as Cuvier and Lamarck, viz: comparison of fossils with living forms, and his results re of great importance. In his "*Tableau des genres végétaux ssiles*," etc., published in Paris in 1849, he gives the classifican and distribution of the genera of fossil plants, and traces t the historical progression of vegetable life on the globe, as had done to a great extent in his previous works. He ows that the cryptogamic forms prevailed in the primary mations; the conifers and cycads in the secondary, and the her forms in the Tertiary, while four fifths of living plants exogens.

In England, Lindley and Hutton published, in 1831–37, a luable work in three volumes, entitled, "Fossil Flora of eat Britain." This work was illustrated by many accurate ites, in which the plants of the coal formation were especially presented. Henry Witham also published two works in 1831 1 1833, in which he treated especially of the internal struce of fossil plants. "Antediluvian Phytology," by Artis, s published in London in 1838. Bowerbank's "History of Fossil Fruits and Seeds of the London Clay," appeared in 43. Hooker's memoir "On the Vegetation of the Carbonrous Period as compared with that of the present day," pubed in 1848, was an important contribution to the science. nbury, Williamson, and others, also published various pers on fossil plants. This branch of Palæontology, hower, attracted much less attention in England, than on the ntinent.

In Germany, the study of fossil plants dates back to the ginning of the century. Von Schlotheim, a pupil of Werr, published in 1804 an illustrated volume on this subject. more important work was that of Count Sternberg, issued 1820–38, and illustrated with excellent plates. Cotta in 32 published a book with the title, "*Die Dendrolithen*," in ich he gave the results of his investigations on the inner ucture of fossil plants. Von Gutbier in 1835, and Germar 1844–53, described and figured the plants of two important alities in Germany. Corda's "*Beiträge zur Flora der rwelt*," issued at Prague, in 1845, was essentially a continu-

* *Prodrome d'une histoire des végétaux fossiles.* 8vo. Paris, 1828.

ation of the work of Sternberg. Unger's "*Chloris protogæa*," 1841–45, "*Genera et species plantarum fossilium*," 1850, and his larger work published in 1852, are all standard authorities. In the latter, the theory of descent is applied to the vegetable world. Schimper and Mougeot's "Monograph on the fossil plants of the Vosges," 1845, was well illustrated, and contained noteworthy results.

Göppert, in 1836, published a valuable memoir entitled, "*Systema Filicum Fossilium*," in which he made known the results of his study of fossil ferns. In the same year, this botanist began a series of experiments, in which he attempted to imitate the process of fossilization, as found in nature. He steeped various animal and vegetable substances in waters holding, some calcareous, others siliceous, and others metallic matter in solution. After a slow saturation, the substances were dried, and exposed to heat until the organic matters were burned. In this way Göppert successfully imitated various processes of petrifaction, and explained many things in regard to fossils that had previously been in question. His discovery of the remains of plants throughout the interior of coal did much to clear up the doubts about the formation of that substance. In 1841, Göppert published an important work in which he compared the genera of fossil plants with those now living. In 1852, another extensive work by this author appeared, entitled, "*Fossile Flora des Uebergangs-Gebirges*."

Andræ, Braun, Dunker, Ettinsghausen, Geinitz, and Goldenberg, all made notable contributions to fossil Botany in Germany, during the period we are now considering.

The systematic study of invertebrate fossils, so admirably begun by Lamarck, was continued actively in France. The Tertiary shells of the Seine valley were further investigated by Defrance, and especially by Deshayes, whose great work on this subject was begun in 1824.* DesMoulin's essay on *Sphérulites* in 1826, Blainville's memoir on *Belemnites* in 1827, Férussac's various memoirs on land and fresh water fossil shells, were valuable additions to the subject. A later work of great importance was D'Orbigny's *Paléontologie Française*, 1840–44, which described the mollusca and radiates in detail, according to formations. The other publications of this author are both numerous and valuable. Brongniart and Desmarest's "*Histoire naturelle des Crustacés Fossiles*," published in 1822, is a pioneer work on this subject. Michelins' memoir on the fossil corals of France, 1841–46, was another important contribution to palæontology. Agassiz's works on fossil Echinoderms and Mollusks are valuable contributions to the science. The

* *Description des coquilles fossiles des environs de Paris.* 3 vols. Paris, 1824–37.

works of d'Archiac, Coquand, Cotteau, Desor, Edwards, Haime, and De Verneuil, are likewise of permanent value.

In Italy, Bellardi, Merian, Michellotti, Phillipi, Zigno, and others, contributed important results to Palæontology.

In Belgium, Bosquet, Nyst, Koninck, Ryckholt, Van Beneden, and others, have all aided materially in the progress of the science.

In England, also, invertebrate fossils were studied with care, and continued progress was made. Sowerby's "Mineral Conchology of Great Britain," in six volumes, a systematic work of great value, was published in 1812–30, and soon after was translated into French and German. Its figures of fossil shells are excellent, and it is still a standard work. Miller's "Natural History of the Crinoidea," published at Bristol, in 1821, and Austin's later monograph, are valuable for reference. Brown's "Fossil Conchology of Britain and Ireland" appeared in 1839, and Brodie's History of the Fossil Insects of England, in 1845. Phillips' illustration of the geology of Yorkshire, 1829–36, and his work on the Palæozoic fossils of Cornwall, Devonshire, and West Somerset, 1843, contained a great deal of original matter in regard to fossil remains. Morris' "Catalogue of British Fossils," issued in 1843, and the later edition in 1854, is most useful to the working palæontologist. The memoirs of Davidson on the Brachiopoda, Edwards, Forbes, Morris, Lycett, Sharpe, and Wood on other Mollusca, Wright on the Echinoderms, Salter on Crustacea, Busk on Polyzoa, Jones on the Entomostraca, and Duncan and Lonsdale on Corals, are of especial value. King's volume on Permian fossils, Mantell's various memoirs, Dixon's work on the fossils of Sussex, 1850, and McCoy's works on Palæozoic fossils, all deserve honorable mention. Sedgwick, Murchison, and Lyell, although their greatest services were in systematic geology, each contributed important results to the kindred science of palæontology during the period we are reviewing.

In Germany, Schlotheim's treatise, "*Die Petrifactenkunde,*" published at Gotha in 1820, did much to promote a general interest in fossils. By far the most important work issued on this subject was the "*Petrifacta Germanica,*" by Goldfuss, in three folio volumes, 1826 to 1844, which has lost little of its value. Bronn's "*Geschichte der Natur,*" 1841–46, was a work of great labor, and one of the most useful in the literature of this period. The author gave a list of all the known fossil species, with full references, and also their distribution through the various formations. This gave exact data on which to base generalizations, hitherto of comparatively little value.

Among other early works of interest in this department may be mentioned, Dalman's memoir on *Trilobites*, 1828, and Bur-

meister's on the same subject, 1843. Giebel's well known "*Fauna der Vorwelt,*" 1847–1856, gave lists of all the fossils described up to that time, and hence is a very useful work. The "*Lethæa Geognostica*" by Bronn, 1834–38, and the second edition by Bronn and Roemer, 1846–56, is a comprehensive general treatise on Palæontology, and the most valuable work of the kind yet published.

The researches of Ehrenberg, in regard to the lowest forms of animals and plants, threw much light on various points in Palæontology, and showed the origin of extensive deposits, the nature of which had before been in doubt. Von Buch, Barrande, Beyrich, Berendt, Dunker, Geinitz, Heer, Hörnes, Klipstein, Von Münster, Reuss, Roemer, Sandberger, Suess, Von Hagenow, Von Hauer, Zeiten, and many others, all aided in the advancement of this branch of science. Angelin, Hisinger, and Nilsson, in Scandinavia; Abich, DeWaldheim, Eichwald, Keyserling, Kutorga, Nordmann, Pander, Rouillier, and Volborth, in Russia; and Pusch in Poland, published important results on fossil invertebrates.

The impetus given by Cuvier to the study of vertebrate fossils extended over Europe, and great efforts were made to continue discoveries in the direction he had so admirably pointed out.

Louis Agassiz (1807–73), a pupil of Cuvier, and long an honored member of this association, attained eminence in the study of ancient as well as of recent life. His great work on Fossil Fishes* deserves to rank next to Cuvier's "*Ossemens Fossiles.*" The latter contained mainly fossil mammals and reptiles, while the fishes were left without a historian till Agassiz began his investigations. His studies had admirably fitted him for the task, and his industry brought together a vast array of facts bearing on the subject. The value of this grand work consists not only in its faithful descriptions and plates, but also in the more profound results it contained. Agassiz first showed that there is a correspondence between the succession of fishes in the rocks, and their embryonal development. This is now thought to be one of the strongest points in favor of evolution, although its discoverer interpreted the facts as bearing the other way.

Pander's memoirs on the fossil fishes of Russia form a worthy supplement to Agassiz's classic work. Brandt's publications are likewise of great value; and those of Lund, in Sweden, have an especial interest to Americans, in consequence of his researches in the caves of Brazil.

Croizet and Jobert's "*Recherches sur les ossemens fossiles du départment du Puy-de-Dôme,*" published in 1828, contained

* *Recherches sur les Poissons fossiles*, 1833–45.

valuable results in regard to fossil mammals. Geoffroy St. Hilaire's researches on fossil Reptiles, published in 1831, were an important advance. De Serres and De Christol's explorations in the caverns in the South of France, published between 1829 and 1839, were of much value. Schmerling's researches in the caverns of Belgium, published in 1833–36, were especially important on account of the discovery of human remains mingled with those of extinct animals. Deslongchamp's memoirs on fossil reptiles, 1835, are still of great interest. Pictet's general treatise on palæontology was a valuable addition to the literature, and has done much to encourage the study of fossils.* DeBlainville, in his grand work, "*Ostéographie*," issued in 1839–56, brought together the remains of living and extinct vertebrates, forming a series of the greatest value for study. Aymard and Pomel's contributions to vertebrate Palæontology are both of value. Gervais and Lartet added much to our knowledge of the subject, and Bravard and Hébert's memoirs are well known.

The brilliant discoveries of Cuvier in the Paris Basin, excited great interest in England, and when it was found that the same Tertiary strata existed in the south of England, careful search was made for vertebrate fossils. Remains of some of the same genera described by Cuvier were soon discovered, and other extinct animals new to science were found in various parts of the kingdom. König, to whom we owe the name *Ichthyosaurus*, and Conybeare, who gave the generic designation *Plesiosaurus*, and also *Mosasaurus*, were among the earliest writers in England on fossil reptiles. The discovery of these three extinct types, and the discussion as to their nature, forms a most interesting chapter in the annals of Palæontology. The discovery of the *Iguanodon*, by Mantell, and the *Megalosaurus*, by Buckland, excited still higher interest. These great reptiles differed much more widely from living forms than the mammals described by Cuvier, and the period in which they lived soon became known as the "age of Reptiles." The subsequent researches of these authors added largely to the existing knowledge of various extinct forms, and their writings did much to arouse public interest in the subject.

Richard Owen, a pupil of Cuvier, followed, and brought to bear upon the subject an extensive knowledge of comparative anatomy, and a wide acquaintance with existing forms. His contributions have enriched almost every department of palæontology, and of extinct vertebrates especially, he has been, since Cuvier, the chief historian. The fossil reptiles of

* "*Traité élémentaire de paléontologie*," etc., *Genève*. 4 vols. 1844–46. Second Edition. Paris, 1853–55.

England, he has systematically described, as well as those of South Africa. The extinct Struthious birds of New Zealand, he has made known to science, and accurately described in extended memoirs. His researches on the fossil mammals of Great Britain, the extinct Edentates of South America, and the ancient Marsupials of Australia, each forms an important chapter in the history of our science.

The personal researches of Falconer and Cautley in the Sewalik Hills of India brought to light a marvelous vertebrate fauna of Pliocene age. The remains thus secured were made known in their great work, "*Fauna Antiqua Sivalensis*," published at London in 1845. The important contributions of Egerton to our knowledge of fossil fishes, and Jardine's well known work, "Ichnology of Annandale," also belong to this period.

The study of vertebrate fossils in Germany was prosecuted with much success during the present period. Blumenbach, the ethnologist, in several publications between 1803 and 1814, recorded valuable observations on this subject. In 1812, Sömmerring gave an excellent figure of a pterodactyle, which he named and described. Goldfuss' researches on the fossil vertebrates from the Caves of Germany, published in 1820–23, made known the more important facts of that interesting fauna. His later publications on extinct Amphibians and Reptiles were also noteworthy. Jäger's investigations on the extinct vertebrate fauna of Wurtemberg, published between 1824 and 1839, were an important advance. To Plieninger's researches in the same region, 1834–44, we owe the discovery of the first Triassic mammal (*Microlestes*), as well as important information in regard to Labyrinthodonts. Kaup's researches on fossil mammals, 1832–41, brought to light many interesting forms, and to him we are indebted for the generic name *Dinotherium*, and excellent descriptions of the remains then known.

Count Münster's "*Beiträge zur Petrifacten-Kunde*," published 1843–46, contained several valuable papers on fossil vertebrates; and the separate papers by the same author are of interest. Andreas Wagner wrote on Pterosaurians in 1837, and later gave the first description of fossil mammals of the Tertiary of Greece, 1837–40. Johannes Müller published an important illustrated work on the Zeuglodonts, in 1849, and various notable memoirs; and Quenstedt, interesting descriptions of fossil reptiles, as well as other papers of much value. Rütimeyer's suggestive memoirs are widely known.

Hermann von Meyer's contributions to vertebrate palæontology are by far the most important published in Germany during the period we are now considering. From 1830, his

investigations on this subject were continuous for nearly forty years, and his various publications are all of value. His "*Beiträge zur Petrifactenkunde,*" 1831–33, contains a series of valuable memoirs. His "*Palæologica,*" issued in 1832, includes a synopsis of the fossil vertebrates then known, with much original matter. His great work, "*Zur Fauna der Vorwelt,*" 1845–60, includes a series of monographs invaluable to the student of vertebrate palæontology. This work, as well as his other chief publications, was illustrated with admirable plates from his own drawings. Other memoirs by this author will be found in the "*Palæontographica,*" of which he was one of the editors. In the many volumes of this publication, which began in 1851, and is still continued, will be found much to interest the investigator in any branch of palæontology.

The "Palæontographical Society of London," established in 1847, has also issued a series of volumes containing valuable memoirs in various branches of Palæontology. These two publications together are a storehouse of knowledge in regard to extinct forms of animal and vegetable life.

It may be interesting here to note briefly the use of general terms in Palæontology, as the gradual progress of the science was indicated to some extent in its terminology. At first, and for a long time, the name "*fossil*" was appropriately used for objects dug from the earth, both minerals and organic remains. The term "Oryctology," having essentially the same meaning, was also used for this branch of study. For a long period, too, the termination *ites* (λίθος, a stone) was applied to fossils to distinguish them from the corresponding living forms; as, for instance, "*Ostracites,*" used by Pliny. At a later date, the general name "figured stones" (*lapides figurati*) was extensively used; and less frequently, "Deluge stones" (*lapides diluviani*). The term "organized fossils" was used to distinguish fossils from minerals, when the real difference became known, although the name "*Reliquiæ*" was sometimes employed. The term "petrifactions" (*Petrificata*) was defined by John Gesner in his work on fossils in 1758, and was afterwards extensively used. Palæontology is comparatively a modern term, having come into use only within the last half century. It was introduced about 1830, and soon was generally adopted in France and England; but in Germany it met with less favor, though used to some extent.

It would be interesting, too, did time permit, to trace the various opinions and superstitions, held at different times, in regard to some of the more common fossils, for example, the Ammonite, or the Belemnite. Of their supposed celestial

origin; of their use as medicine by the ancients, and in the East to-day; of their marvellous power as charms, among the Romans, and still among the American Indians. It would be instructive, also, to compare the various views expressed by students in science, concerning some of the stranger extinct forms, for instance, the Nummulites, among Protozoa; the Rudistes, among Mollusks; or the Mosasaurus, among Reptiles. Dissimilar as such views were, they indicate in many cases gropings after truth,—natural steps in the increase of knowledge.

The third period in the history of Palæontology, which, as I have said, began with Cuvier and Lamarck at the beginning of the present century, forms a natural epoch extending through six decades. The definite characteristics of this period, as stated, were dominant during all this time, and the progress of Palæontology was commensurate with that of intelligence and culture.

For the first half of this period, the marvelous discoveries in the Paris Basin excited astonishment, and absorbed attention; but the real significance and value of the facts made known by Cuvier, Lamarck, and William Smith, were not appreciated. There was still a strong tendency to regard fossils merely as interesting objects of natural history, as in the previous period, and not as the key to profounder problems in the earth's history. Many prominent geologists were still endeavoring to identify formations in different countries by their mineral characters, rather than by the fossils imbedded in them. Such names as "Old Red Sandstone," and "New Red Sandstone," were given in accordance with this opinion. Humboldt, for example, attempted to compare the formations of South America and Europe by their mineral features, and doubted the value of fossils for this purpose. In 1823, he wrote as follows: "Are we justified in concluding that all formations are characterized by particular species? that the fossil shells of the chalk, the muschelkalk, the Jura limestone, and the Alpine limestones, are all different? I think this would be pushing the induction much too far."* Jameson still thought minerals more important than fossils for characterizing formations; while Bakewell, later yet, defines Palæontology as comprising "Fossil Zoology and Fossil Botany, a knowledge of which may appear to the student as having little connection with Geology."

During the later half of the third period, greater progress was made, and before its close Geology was thoroughly established as a science. Let us consider for a moment what had really been accomplished up to this time.

It had now been proved beyond question that portions at least of the Earth's surface had been covered many times by

* *Essai géognostique sur le gisement des Roches*, p. 41.

the sea, with alternations of fresh water and of land; that the strata thus deposited were formed in succession, the lowest of the series being the oldest; that a distinct succession of animals and plants had inhabited the earth during the different geological periods; and that the order of succession found in one part of the earth was essentially the same in all. More than 30,000 new species of extinct animals and plants had now been described. It had been found, too, that from the oldest formations to the most recent, there had been an advance in the grade of life, both animal and vegetable, the oldest forms being among the simplest, and the higher forms successively making their appearance.

It had now become clearly evident, moreover, that the fossils from the older formations were all extinct species, and that only in the most recent deposits were there remains of forms still living. The equally important fact had been established, that in several groups of both animals and plants, the extinct forms were vastly more numerous than the living; while several orders of fossil animals had no representatives in modern times. Human remains had been found mingled with those of extinct animals, but the association was regarded as an accidental one by the authorities in science; and the very recent appearance of Man on the earth was not seriously questioned. Another important conclusion reached, mainly through the labors of Lyell, was, that the earth had not been subjected in the past to sudden and violent revolutions; but the great changes wrought had been gradual, differing in no essential respect from those still in progress. Strangely enough, the corollary to this proposition, that Life, too, had been continuous on the earth, formed at that date no part of the common stock of knowledge.

In the physical world, the great law of "Correlation of forces" had been announced, and widely accepted; but in the organic world, the dogma of the miraculous creation of each separate species still held sway, almost as completely as when Linnæus declared: "There are as many different species as there were different forms created in the beginning by the Infinite Being." But the dawn of a new era was already breaking, and the third period of palæontology we may consider now at an end.

Just twenty years ago, science had reached a point when the belief in "special creations" was undermined by well established facts, slowly accumulated. The time was ripe. Many naturalists were working at the problem, convinced that Evolution was the key to the present and the past. But how had Nature brought this change about? While others pondered, Darwin spoke the magic word — "*Natural Selection*," and a new epoch in science began.

The fourth period in the history of Palæontology dates from this time, and is the period of to-day. One of the main characteristics of this epoch is the belief that *all life, living and extinct, has been evolved from simple forms.* Another prominent feature is the accepted fact of *the great antiquity of the human race.* These are quite sufficient to distinguish this period sharply from those that preceded it.

The publication of Charles Darwin's work on the "Origin of Species," November, 1859, at once aroused attention, and started a revolution which has already in the short space of two decades changed the whole course of scientific thought. The theory of "Natural Selection," or as Spencer has happily termed it, the "Survival of the Fittest," had been worked out independently by Wallace, who justly shares the honor of the discovery. We have seen that the theory of Evolution was proposed and advocated by Lamarck, but he was before his time. The anonymous author of the "Vestiges of Creation," which appeared in 1844, advocated a somewhat similar theory which attracted much attention, but the belief that species were immutable was not sensibly affected until Darwin's work appeared.

The difference between Lamarck and Darwin is essentially this: Lamarck proposed the theory of Evolution; Darwin changed this into a doctrine, which is now guiding the investigations in all departments of biology. Lamarck failed to realize the importance of time, and the interaction of life on life. Darwin, by combining these influences with those also suggested by Lamarck, has shown *how* the existing forms on the earth may have been derived from those of the past.

This revolution has influenced Palæontology as extensively as any other department of science, and hence the new period we are discussing. In the last epoch, species were represented independently, by parallel lines; in the present period, they are indicated by dependent, branching lines. The former was the analytic, the latter is the synthetic, period. To-day, the animals and plants now living are believed to be genetically connected with those of the distant past; and the palæontologist no longer deems species of the first importance, but seeks for relationships and genealogies, connecting the past with the present. Working in this spirit, and with such a method, the advance during the last decade has been great, and is an earnest of what is yet to come.

The progress of Palæontology in Great Britain during the present period has been great, and the general interest in the science much extended. The views of Darwin soon found acceptance here. Next to his discovery of "Natural Selection,"

Darwin was fortunate in having so able and bold an expounder as Huxley; who was one of the first to adopt his theory, and give it a vigorous support. Huxley's masterly researches have been of great benefit to all departments of Biology, and his contributions to Palæontology are invaluable. Among the latter, his original investigations on the relations of Birds and Reptiles are especially noteworthy. His various memoirs on extinct Reptiles, Amphibians and Fishes, belong to the permanent literature of the subject. The important researches of Owen on the fossil vertebrates have been continued to the present time. He has added largely to his previous publications on the British fossil Reptiles, Birds, and Mammals; the extinct reptiles of South Africa, and the Post-Tertiary birds of New Zealand. His description of the *Archæopteryx* near the beginning of the period was a most welcome contribution.

The investigations of Egerton on Fossil Fishes have likewise been continued with important results. Busk, Dawkins, Flower and Sanford have made valuable contributions to the history of fossil Mammals. Bell, Günther, Hulke, Lankester, Powrie, Miall, and Seely, have made notable additions to our knowledge of Reptiles, Amphibians, and Fishes. Among Invertebrates, the Crustacea have been especially studied by Jones, Salter, and Woodward. Davidson, Etheridge, Lycett, Morris, Phillips, Wood, and Wright have continued their researches on the Mollusks; Duncan, Nicholson and others have investigated the extinct Corals; and Binney, Carruthers, and Williamson, the Fossil Plants. Numerous other important contributions have been made to the science in Great Britain during the present period.

On the Continent, the advance in Palæontology has, during the last two decades, been equally great. In France, Gervais continued his memoirs on extinct vertebrates nearly to the present date; while Gaudry has published several volumes on the subject that are models for all students of the science. His work on the fossil animals of Greece is a perfect monograph of its kind, and his later publications are all of importance. Lartet's various works are of permanent value, and his application of Palæontology to Archæology brought notable results. The volume of Alphonse Milne-Edwards on fossil Crustacea was a fit supplement to Brongniart and Desmarest's well known work; while his grand memoir on fossil Birds deserves to rank with the classic volumes of Cuvier. Duvernoy, Filhol, Hébert, Sauvage and others have also published interesting results on fossil vertebrates.

Van Beneden's researches on the fossil vertebrates of Belgium have produced results of great value. Pictet, Rütimeyer, and Wedersheim in Switzerland, Bianconi, Forsyth-Major, and

Sismonda in Italy, and Nodot in Spain, have likewise published important memoirs. The extinct vertebrates have been studied in Germany by Von Meyer, Carus, Fraas, Giebel, Haeckel, Haase, Hensel, Kayser, Kner, Ludwig, Peters, Portis, Maack, Salenka, Zittel, and many others; in Holland by Winkler, in Denmark by Reinhardt; and in Russia by Brandt and Kowalewsky.

The fossil invertebrates have been investigated with care by D'Archiac, D'Orbigny, Bayle, Fromentel, Oustalet, and others in France; Desor, Loriol and Roux in Switzerland; Cappellini, Massalongo, Michellotti, Meneghini, and Sismonda in Italy, Barrande, Benecke, Beyrich, Dames, Dorn, Ehlers, Geinitz, Giebel, Gümbel, Feistmantel, Hagen, von Hauer, von Heyden, von Fritsch, Laube, Oppel, Quenstedt, Roemer, Schlüter, Suess, Speyer, and Zittel in Germany. The fossil Plants have been studied in these countries by Massalongo, Saporta, Zigno, Fiedler, Goldenberg, Gehler, Heer, Goeppert, Ludwig, Schimper, Schenk, and many others.

Among the recent researches in Palæontology in other regions may be mentioned those of Blanford, Feistmantel, Lydekker, and Stoliczka, in India; Haast and Hector in New Zealand, and Krefft and McCoy in Australia; all of whom have published valuable results.

Of the progress of palæontology in America, I have thus far said nothing, and I need now say but little, as many of you are doubtless familiar with its main features. During the first and second periods in the history of palæontology, as I have defined them, America, for most excellent reasons, took no part. In the present century, during the third period, appear the names of Bigsby, Green, Morton, Mitchell, Rafinesque, Say, and Troost, all of whom deserve mention. More recently, the researches of Conrad, Dana, Deane, DeKay, Emmons, Gibbes, Hitchcock, Holmes, Lea, McChesney, Owen, Redfield, Rogers, Shumard, Swallow, and many others, have enlarged our knowledge of the fossils of this country.

The contributions of James Hall to the Invertebrate Palæontology of this country form the basis of our present knowledge of the subject. The extensive labors of Meek in the same department are likewise entitled to great credit, and will form an important chapter in the history of the science. The memoirs of Billings, Gabb, Scudder, White, and Whitfield are numerous and important; and the publications of Derby, Hartt, James, Miller, Shaler, Rathburn, and Winchell, are also of value. To Dawson, Lesquereux, and Newberry, we mainly owe our present knowledge of the fossil plants of this country.

The foundation of our vertebrate Palæontology was laid by Leidy, whose contributions have enriched nearly every department of the subject. The numerous publications of Cope are well known. Agassiz, Allen, Baird, Dawson, Deane, DeKay, Emmons, Gibbes, Harlan, Hitchcock, Jefferson, Lea, LeConte, Newberry, Redfield, St. John, Warren, Whitney, Worthen, Wyman, and others, have all added to our knowledge of American fossil vertebrates. The chief results in this department of our subject, I have already laid before you on a previous occasion, and hence need not dwell upon them here.

In this rapid sketch of the history of Palæontology, I have thought it best to speak of the earlier periods more in detail, as they are less generally known, and especially as they indicate the growth of the science, and the obstacles it had to surmount. With the present work in palæontology, moreover, you are all more or less familiar, as the results are now part of the current literature. To assign every important discovery to its author, would have led me far beyond my present plan. I have only endeavored to indicate the growth of the science by citing the more prominent works that mark its progress, or illustrate the prevailing opinions and state of knowledge at the time they were written.

In considering what has been accomplished, directly or indirectly, it is well to bear in mind that without palæontology there would have been no science of geology. The latter science originated from the study of fossils, and not the reverse, as generally supposed. Palæontology, therefore, is not a mere branch of geology, but the foundation on which that science mainly rests. This fact is a sufficient excuse, if one were wanting, for noting the early opinions in regard to the changes of the earth's surface, as these changes were first studied to explain the position of fossils. The investigation of the latter first led to theories of the earth's formation, and thus to geology. When speculation replaced observation, fossils were discarded, and for a time the mineral characters of strata were thought to be the key to their position and age. For some time after this, geologists, as we have seen, apologized for using fossils to determine formations, but for the last half century their value for this purpose has been fully recognized.

The services which Palæontology has rendered to Botany and Zoology are less easy to estimate, but are very extensive. The classification of these sciences has been rendered much more complete by the intercalation of many intermediate forms. The probable origin of various living species has been indicated by the genealogies suggested by extinct types; while our knowledge of the geographical distribution of animals and

plants at the present day has been greatly improved by the facts brought out in regard to the former distribution of life on the globe.

Among the vast number of new species which have been added are the representatives of a number of new orders entirely unknown among living forms. The distribution of these extinct orders, among the different classes, is interesting, as they are mainly confined to the higher groups. Among the fossil Plants, no new orders have yet been found. There are none known among the Protozoa, or the Mollusca. The Radiates have been enriched by the extinct orders of Blastoidea, Cystidea, and Edrioasterida; and the Crustaceans by the Eurypterida and Trilobita. Among the Vertebrates, no extinct order of fossil Fishes has yet been found; but the Amphibians have been enlarged by the important order Labyrinthodonta. The greatest additions have been among the Reptiles, where the majority of the orders are extinct. Here we have at the present date the Ichthyosauria, Sauranodontia, Plesiosauria and Mosasauria, among the marine forms; the Pterosauria, including the Pteranodontia, containing the flying forms; and the Dinosauria, including the Sauropoda—the giants among reptiles; likewise the Dicynodontia, and probably the Theriodontia, among the terrestrial forms. Although but few fossil Birds have been found below the Tertiary, we have already among the Mesozoic forms three new orders: the Saururæ, represented by *Archæopteryx;* the Odontotormæ, with *Ichthyornis* as the type; and the Odontolcæ, based upon *Hesperornis;* all of these orders being included in the sub-class Odontornithes, or toothed birds. Among Mammals, the new groups regarded as orders are the Toxodontia, and the Dinocerata, among the Ungulates; and the Tillodontia, including strange Eocene Mammals whose exact affinities are yet to be determined.

Among the important results in vertebrate palæontology, are the genealogies, made out with considerable probability, for various existing animals. Many of the larger mammals have been traced back through allied forms in a closely connected series to early Tertiary times. In several cases the series are so complete that there can be little doubt that the line of descent has been established. The Evolution of the horse, for example, is to-day demonstrated by the specimens now known. The demonstration in one case stands for all. The evidence in favor of the genealogy of the horse now rests on the same foundation as the proof that any fossil bone once formed part of the skeleton of a living animal. A special creation of a single bone is as probable as the special creation of a single species. The method of the palæontologist in the investigation

of the one, is the method for the other. The only choice lies between natural derivation and supernatural creation.

For such reasons it is now regarded among the active workers in science as a waste of time to discuss the truth of Evolution. The battle on this point has been fought, and won.

The geographical distribution of animals and plants, as well as their migrations, has received much new light from Palæontology. The fossils found in some natural divisions of the earth are related so closely to the forms now living there, that a genetic connection between them can hardly be doubted. The extinct Marsupials of Australia, and the Edentates of South America, are well known examples. The Pliocene hippopotami of Asia and the South of Europe point directly to migrations from Africa. Other similar examples are numerous. The fossil plants of the Arctic region prove the existence of a climate there far milder than at present, and recent researches at least render more probable the suggestion, made long ago by Buffon, in his "Epochs of Nature," that life began in the polar regions, and by successive migrations from them the continents were peopled.

The great services which Comparative Anatomy rendered to Palæontology at the hands of Cuvier, Agassiz, Owen, and others, have been amply repaid. The solution of some of the most difficult problems in Anatomy has received scarcely less aid from the extinct forms discovered, than from Embryology; and the two lines of research supplement each other. Our present knowledge of the vertebrate skull, the limb-arches, and the limbs, has been much enlarged by researches in Palæontology. On the other hand, the recent labors of Gegenbaur, Huxley, Parker, Balfour, and Thacher, will make clear many obscure points in ancient Life.

One of the important results of recent palæontological research, is the law of brain-growth, found to exist among extinct mammals, and to some extent in other vertebrates. According to this law, as I have briefly stated it elsewhere: "All Tertiary mammals had small brains. There was, also, a gradual increase in the size of the brain during this period. This increase was confined mainly to the cerebral hemispheres, or higher portions of the brain. In some groups, the convolutions of the brain have gradually become more complicated. In some, the cerebellum and the olfactory lobes have even diminished in size." More recent researches render it probable that the same general law of brain-growth holds good for birds and reptiles from the Mesozoic to the present time. The Cre-

taceous birds, that have been investigated with reference to this point, had brains only about one-third as large in proportion as those nearest allied among living species. The Dinosaurs from our Western Jurassic follow the same law, and had brain cavities vastly smaller than any existing reptiles. Many other facts point in the same direction, and indicate that the general law will hold good for all extinct vertebrates.

Palæontology has rendered great service to the more recent science of Archæology. At the beginning of the present period, a re-examination of the evidence in regard to the antiquity of the human race was going on, and important results were soon attained. Evidence in favor of the presence of man on the earth at a period far earlier than the accepted chronology of six thousand years would imply, had been gradually accumulating; but had been rejected from time to time by the highest authorities. In 1823, Cuvier, Brongniart, and Buckland, and later, Lyell, refused to admit that human relics, and the bones of extinct animals found with them, were of the same geological age, although experienced geologists, such as Boué and others, had been convinced by collecting them. Christol, Serres, and Tournal, in France, and Schmerling in Belgium, had found human remains in caves, associated closely with those of various extinct mammals, and other similar facts were on record.

Boucher de Perthes, in 1841, began to collect stone implements in the gravels of the valley of the Somme, and, in 1847, published the first volume of his "*Antiquités Celtiques*." In this work, he described the specimens he had found, and asserted their great antiquity. The facts as presented, however, were not generally accepted. Twelve years later, Falconer, Evans, and Prestwich examined the same localities with care, became convinced, and the results were published in 1859 and 1860. About the same time Gaudry, Hébert, and Desnoyers, also explored the same valley, and announced that the stone implements there were as ancient as the mammoth and rhinoceros found with them. Explorations in the Swiss lakes and in the Danish shell heaps added new testimony bearing in the same direction. In 1863, appeared Lyell's work on the "Geological Evidences of the Antiquity of Man," in which facts were brought together from various parts of the world, proving beyond question the great age of the human race.

The additional proof since brought to light has been extensive, and is still rapidly increasing. The Quaternary age of man is now generally accepted. Attempts have recently been made to approximate in years the time of man's first appearance on the earth. One high authority has estimated the antiquity of man merely to the last glacial epoch of Europe as

250,000 years; and those best qualified to judge, would, I think, regard this as a fair estimate.

Important evidence has likewise been adduced of man's existence in the Tertiary, both in Europe and America. The evidence to-day is in favor of the presence of man in the Pliocene of this country. The proof offered on this point by Professor J. D. Whitney, in his recent work,* is so strong, and his careful, conscientious method of investigation so well known, that his conclusions seem irresistible. Whether the Pliocene strata he has explored so fully on the Pacific coast corresponds strictly with the deposits which bear this name in Europe, may be a question requiring further consideration. At present, the known facts indicate that the American beds containing human remains, and works of man, are as old as the Pliocene of Europe. The existence of Man in the Tertiary period seems now fairly established.

In looking back over the history of Palæontology, much seems to have been accomplished; and yet the work has but just begun. A small fraction only of the earth's surface has been examined, and two large continents are waiting to be explored. The "imperfection of the geological record," so often cited by friends and foes, still remains, although much improved; but the future is full of promise. In filling out this record, America, I believe, will do her full share, and thus aid in the solution of the great problems now before us.

I have endeavored to define clearly the different periods in the history of Palæontology. If I may venture, in conclusion, to characterize the present period in all departments of science, its main feature would be a *belief in universal laws.* The reign of Law, first recognized in the physical world, has now been extended to Life, as well. In return, Life has given to inanimate nature the key to her profounder mysteries—Evolution, which embraces the universe.

What is to be the main characteristic of the next period? No one now can tell. But if we are permitted to continue in imagination the rapidly converging lines of research pursued to-day, they seem to meet at the point where organic and inorganic nature become one. That this point will yet be reached, I cannot doubt.

* Auriferous Gravels of the Sierra Nevada of California. 1879.

ART. XLII.—*On the Diamagnetic Constants of Bismuth and Calc-spar in Absolute Measure.*

Part I.—By H. A. ROWLAND, Professor of Physics in the Johns Hopkins University.

SINCE my experiments on the magnetic constants of iron, nickel and cobalt, I have sought the means of determining those of some diamagnetic substances, and to that end have described a method in this Journal for May, 1875, (vol. ix, page 357). As Mr. Jacques, Fellow of the University, was willing to take up the experimental portion, I have here worked up the subject more in detail and brought the formulæ into practical shape. No experiments have been made on this subject so far, but some rough comparisons with iron have been made by Becquerel, Plucker and Weber. But as iron varies so greatly, and as the methods of experiment are inexact, we cannot be said to know much about the subject. As, however, the relative results of these experiments and those of Faraday can be accepted as reasonably exact for diamagnetic substances and weak paramagnetic ones, it is only necessary to make a determination of one substance such as bismuth, and then the rest can be readily found. But as bismuth is very crystalline it is necessary to make our formulæ general, unless we use bismuth in a powder, which would introduce error.

The general method of experiment has been indicated in the paper before referred to, but I may here state that it consists in counting the number of vibrations made by a bar hung in the usual manner between the poles of an electromagnet. The distribution of the magnetic force in the field being known, we can then calculate the force acting on the body, and the comparison of this with the time of vibration gives us the means of determining the constant sought. But I will leave the more exact description to be given by Mr. Jacques in the experimental part.

Exploration of field.

The first operation to be performed is to find a formula to express the force of the field at any point, and an experimental means of determining it in absolute measure. The magnet used was one on the method of Ruhmkorff, and hence the field was nearly symmetrical around the axis of the two branches, and also with respect to a plane perpendicular to the axis at a point midway between its poles. Should any want of symmetry exist by accident, it will be nearly neutralized in its effect on the final result, seeing that the diamagnetic bar hangs symmetrically.

The proper expansion of the magnetic potential for this case is therefore a series of zonal spherical harmonics, including only the uneven powers. Hence, if V is the potential,

$$\text{(1)} \qquad V = A_{,} Q_{,} r + A_{,,,} Q_{,,,} r^3 + A_V Q_V r^5 + \text{etc.}$$

where r is the distance from the center of symmetry, $Q_{,}$, $Q_{,,,}$, etc., are the spherical harmonics with respect to the angle between r and the axis, and $A_{,}$, $A_{,,,}$, A_V, etc., are constants to be found by experiment. The only method known of measuring a strong magnetic field with accuracy is by means of induced currents, and in this case I have used a modification of the method of the proof plane as I have described it in this Journal, III, vol. x, p. 14. In the method there described the coil was to be drawn rapidly away from the given point: in the present case the coil was moved along the axis, thus measuring the difference of the field at several points; on then placing it at the center and drawing it away, the field was measured at that point. The field at the other points along this axis could then be found by adding the measured difference to this quantity. This method is far more accurate than the direct measurement at the different points.

When a wire is moved in a magnetic field the current induced in it is equal to the change of its potential energy, supposing it to transmit a unit current, divided by the resistance of the circuit. The potential energy of a wire in a magnetic field is (Maxwell's Elec., Art. 410),

$$P = \int \left(l \frac{dV}{dx} + m \frac{dV}{dy} + n \frac{dV}{dz} \right) dS$$

which is simply the surface integral of V over any surface whose edge is in the wire.

In the present case, take the axis of x in the direction of the axis of the poles and the surface, S, parallel to the plane YZ, and let ρ be the distance in this plane from the center of the coil we are calculating. Then

$$P = 2\pi \int \frac{dV}{dx} \rho d\rho = \pi \int \frac{dV}{dx} d(\rho^2)$$

for a single circle.

From (1)
$$\frac{dV}{dx} = \Sigma^0_\infty (i+1) A_{i+1} r^i Q_i$$

$$\text{and} \qquad \rho^2 = x^2 \left(\frac{1}{\mu^2} - 1 \right); \quad r^i = \frac{x^i}{\mu^i}$$

where $\mu = \cos \theta$

$$\therefore P = -2\pi x^{i+2} \, \Sigma (i+1) A_{i+1} \int_1^\mu \frac{Q_i \, d\mu}{\mu^{i+3}}$$

$$P = 2\pi\rho^2 \, \Sigma^0_\infty \, A_{i+1} \frac{r^i Q_{i+1}}{i+2}$$

For a circle of rectangular section we must obtain the mean value of this quantity throughout the section of the coil.

$$\therefore \mathrm{M} = \frac{1}{\eta\xi}\int_{x_0 - \frac{1}{2}\eta}^{x_0 + \frac{1}{2}\eta}\int_{\rho_0 - \frac{1}{2}\xi}^{\rho_0 + \frac{1}{2}\xi} \mathrm{P}\,dx\,d\rho$$

Where x_0 and ρ_0 are the values of x and ρ at the center of section and η and ξ are the width and depth of the groove in which the coil is wound. We can calculate this quantity best by the formula of Maxwell (Electricity, Art. 700),

$$\mathrm{M} = \mathrm{P}_0 + \tfrac{1}{24}\left(\frac{d^2 p_0}{d\rho^2}\xi^2 + \frac{d^2 p_0}{dx^2}\eta^2\right) + \text{etc.}$$

Thus we finally find

$$\text{(2)} \quad \mathrm{M} = \pi\rho^2\Big\{\mathrm{A}_{,}\left(1 + \tfrac{1}{12}\frac{\xi^2}{\rho^2}\right) + \tfrac{1}{2}\mathrm{A}_{,,,}r^2_0\left(\mathrm{Q}^1_{,,,} + \tfrac{1}{2}(5\mu^2 - 3)\frac{\xi^2}{\rho^2} + \tfrac{1}{2}\frac{\eta^2}{\rho^2}(1 - \mu^2)\right)$$
$$+ \tfrac{1}{8}\mathrm{A}_{\mathrm{v}}\mathrm{Q}^1_{\mathrm{v}}r^4_0 + \text{etc.}\Big\}$$

It is by aid of this equation that we find the coefficients $\mathrm{A}_{,}$, $\mathrm{A}_{,,,}$, etc. in the expansion of the magnetic potential, V. For, let the coil be moved in the field from a position where M has the value M′ to where it has the value M″: then if the coil be joined to a galvanometer the current induced will be equal to

$$\frac{\mathrm{M}' - \mathrm{M}''}{\mathrm{R}}$$

where R is the resistance of the circuit. If an earth inductor is included in the circuit whose integral area is E, when it is reversed the current is $\frac{2\mathrm{HE}}{\mathrm{R}}$ where H is the component of the earth's magnetism perpendicular to the plane of the inductor. The current as measured by the galvanometer in the first case will be $\mathrm{C}\sin\frac{1}{2}\delta\,(1 + \frac{1}{2}\lambda)$ and in the second $\mathrm{C}\sin\frac{1}{2}\mathrm{D}\,(1 + \frac{1}{2}\lambda)$, where C is the constant of the galvanometer and λ is the logarithmic decrement.

Hence

$$\frac{\mathrm{M}' - \mathrm{M}''}{\mathrm{R}} = \mathrm{C}\sin\tfrac{1}{2}\delta\,(1 + \tfrac{1}{2}\lambda)$$

$$\frac{2\mathrm{HE}}{\mathrm{R}} = \mathrm{C}\sin\tfrac{1}{2}\mathrm{D}\,(1 + \tfrac{1}{2}\lambda)$$

$$\therefore \mathrm{M}' - \mathrm{M}'' = 2\mathrm{HE}\frac{\sin\frac{1}{2}\delta}{\sin\frac{1}{2}\mathrm{D}}$$

In this way we can obtain a series of equations containing $\mathrm{A}_{,}$, $\mathrm{A}_{,,,}$, etc., and can thus find these by elimination.

This completes the exploration, and we have as a result a formula giving the magnetic potential of the field in absolute measure throughout a certain small region in which we can experiment.

The next process is to consider the action of this field upon any body which we may hang in it.

Crystalline Body in Magnetic Field.

Let the body have such feeble magnetic action that the magnetic field is not very much influenced by its presence. In all crystalline substances we know there exist in general three axes at right angles to each other, along which the magnetic induction is in the direction of the magnetic force. Let k_1, k_2 and k_3 be the coefficients of magnetization in the directions of these axes and let a set of coördinate axes be drawn parallel to these crystalline axes, the coördinates referred to which are designated by x', y' and z', and the magnetic components of the force parallel to which are X′, Y′ and Z′.

The energy of the crystalline body will then be

$$E = -\tfrac{1}{2}\iiint (k_1 X'^2 + k_2 Y'^2 + k_3 Z'^2)\, dx'dy'dz'$$

In most cases it is more convenient to refer the equation to axes in some other direction through the crystal. Let these axes be X, Y, Z.

Then

$$\begin{aligned} x &= x'\alpha + y'\beta + z'\gamma \\ y &= x'\alpha' + y'\beta' + z'\gamma' \\ z &= x'\alpha'' + y'\beta'' + z'\gamma'' \end{aligned}$$

$$X' = \frac{dV}{dx'} = \frac{dV}{dx}\alpha + \frac{dV}{dy}\alpha' + \frac{dV}{dy}\alpha''$$
$$Y' = \text{etc.}$$

Hence

$$\begin{aligned} X' &= X\alpha + Y\alpha' + Z\alpha'' \\ Y' &= X\beta + Y\beta' + Z\beta'' \\ Z' &= X\gamma + Y\gamma' + Z\gamma'' \end{aligned}$$

where α, β, γ; α', β', γ'; and $\alpha'', \beta'', \gamma''$ are the direction cosines of the new axes with reference to the old.

We then find

$$\begin{aligned} E = -\tfrac{1}{2}\iiint \{ & X^2(k_1\alpha^2 + k_2\beta^2 + k_3\gamma^2) + Y^2(k_1\alpha'^2 + k_2\beta'^2 + k_3\gamma'^2) \\ & + Z^2(k_1\alpha''^2 + k_2\beta''^2 + k_3\gamma''^2) + 2XY(k_1\alpha\alpha' + k_2\beta\beta' + k_3\gamma\gamma') + 2XZ \\ & (k_1\alpha\alpha' + k^2\beta\beta'' + k_3\gamma\gamma'') + 2YZ(k_1\alpha\,\alpha'' + k_2\beta'\beta'' + k_3\gamma'\gamma'')\}\, dx\,dy\,dz \end{aligned}$$

The most simple and in many respects the most interesting cases are when the crystal has only one optic or magnetic axis. In this case $k_2 = k_3$.

Hence

$$E = -\tfrac{1}{2}\iiint \{(X^2 + Y^2 + Z^2)k_2 + (X\alpha + Y\alpha' + Z\alpha'')^2(k_1 - k_2)\}\, dx\,dy\,dz$$

where α, α' and α'' are the direction cosines of the magnetic axis with respect to the coördinate axes.

The first case to consider is that of a mass of crystal in a uniform magnetic field. The magnetic forces which enter the equation are those due to the magnetic action of the body as well as to the field in which the body is placed. In the case of very weak magnetic or diamagnetic bodies the forces are almost entirely those of the field alone. Hence in the case under consideration we may put $Y=0$ and $Z=0$.

Hence

$$E = -\tfrac{1}{2}\iiint X^2\left((k_1-k_2)\,\alpha^2+k_2\right)dx\,dy\,dz,$$

and if v is the volume of the body

$$E = -\tfrac{1}{2}X^2\left((k-k_2)\,\alpha^2+k_2\right)v$$

As this expression is the same at all points of the field there is no force acting to translate the body from one part of the field to another. The moment of the force tending to increase φ, where $\varphi=\cos^{-1}\alpha$, is

$$-\frac{dE}{d\varphi}=v\,X^2\,(k_1-k_2)\sin\varphi\cos\varphi$$

By observing the moment of the force which acts on a crystal placed in a uniform magnetic field we can thus find the value of k_1-k_2 or the difference of the magnetic constant along the axis and at right angles to it. The differences of the constants can also be found in the case of crystals with three axes by a similar process.

The next case which I shall consider is that of a bar hanging in a magnetic field. Let the field be symmetrical around an horizontal axis, and also with reference to a plane perpendicular to that axis at the center. If the bar is very long with reference to its section and a plane can be passed through it and the axis we must have $Z=0$, and the equation becomes

$$E = -\tfrac{1}{2}\iiint\left\{(X^2+Y^2)\,k_2+(X\alpha+Y\alpha')^2\,(k_1-k_2)\right\}dx\,dy\,dz$$

Let the axis of X coincide with the long axis of the bar, as this will in the end lead to the most simple result, seeing that we have to integrate along the length of the bar.

Let r be the length along the bar from the center to any point, and let θ be the angle made by the bar with the axis of symmetry: then

$$X=-\frac{dV}{dr}\qquad Y=-\frac{1}{r}\frac{dV}{d\theta}$$

also let the section of the bar be

$$a=dy\,dz$$

and let the axis of the bar pass through the origin from which we have developed the potential in terms of spherical harmonies. We can then write as before

$$V=A_{\prime}Q_{\prime}\,r+A_{\prime\prime\prime}Q_{\prime\prime\prime}\,r^3+A_{V}Q_{V}\,r^5+\text{etc.}$$

where $Q_{,,}$ $Q_{,,,,}$ etc. are zonal spherical harmonics with reference to the angle θ,

$$X = -\{A_{,} Q_{,} + 3A_{,,,} Q_{,,,} r^2 + 5A_{v} Q_{v} r^4 + \text{etc.}\}$$
$$Y = +\{A_{,} Q'_{,} + A_{,,,} Q'_{,,,} r^2 + A_{v} Q'_{v} r^4 + \text{etc.}\} \sin\theta$$

from which we have the following:

$$X^2 = A^2_{,} Q_{,}^2 + 9A^2_{,,,} Q^2_{,,,} r^4 + 25 A^2_{v} Q^2_{v} r^8 + 6A_{,} A_{,,,} Q_{,} Q_{,,,} r^2 + 10 A_{,} A_{v} Q_{,} Q_{v} r^4 + 30 A_{,,,} A_{v} Q_{,,,} Q_{v} r^6 + \text{etc.}$$

$$Y^2 = \{A^2_{,} Q'^2_{,} + A^2_{,,,} Q'^2_{,,,} r^4 + A_{v} Q'^2_{v} r^8 + 2A_{,} A_{,,,} Q'_{,} Q'_{,,,} r^2 + 2A_{,} A_{v} Q'_{,} Q'_{v} r^4 + 2A_{,,,} A_{v} Q'_{,,,} Q'_{v} r^6 + \text{etc.}\} \sin^2\theta$$

$$XY = -\{A^2_{,} Q_{,} Q'_{,} + 3A^2_{,,,} Q_{,,,} Q'_{,,,} r^4 + 5A^2_{v} Q_{v} Q'_{v} r^8 + (3Q'_{,} Q_{,,,} + Q_{,} Q'_{,,,}) A_{,} A_{,,,} r^2 + (5Q'_{,} Q_{v} + Q_{,} Q'_{v}) A_{,} A_{v} r^4 + (5Q'_{,,,} Q_{v} + 3Q_{,,,} Q'_{v}) A_{,,,} A_{v} r^6 + \text{etc.}\} \sin\theta$$

The moment of the force tending to increase θ is

$$\Theta = -\frac{dE}{d\theta}$$

whence we may write,

$$\Theta = -\tfrac{1}{2}a\{A((k_1 - k_2)\alpha^2 + k_2) + B((k_1 - k_2)\alpha'^2 + k_2) - C(k_1 - k_2)\alpha\alpha'\}$$

where
$$A = -\frac{d}{d\theta}\int_{-l}^{+l} X^2\, dr = \sin\theta \frac{d}{d\mu}\int_{-l}^{+l} X^2\, dr$$
$$B = -\frac{d}{d\theta}\int_{-l}^{+l} Y^2\, dr = \sin\theta \frac{d}{d\mu}\int_{-l}^{+l} Y^2\, dr$$
$$C = -\frac{d}{d\theta}\int_{-1}^{+l} 2XY dr = \sin\theta \frac{d}{d\mu}\int_{-1}^{+l} 2XY\, dr$$

where l is half the length of the bar and $\mu = \cos\theta$.

$$A = 4l \sin\theta\{A^2_{,} Q_{,} Q'_{,} + \tfrac{9}{5}A^2_{,,,} Q_{,,,} Q'_{,,,} l^4 + \tfrac{25}{9}A^2_{v} Q_{v} Q'_{v} l^8 + A_{,} A_{,,,}(Q'_{,} Q_{,,,} + Q_{,} Q'_{,,,}) l^2 + A_{,} A_{v}(Q'_{,} Q_{v} + Q_{,} Q'_{v}) l^4 + \tfrac{15}{7}A_{,,,} A_{v}(Q'_{,,,} Q_{v} + Q_{,,,} Q'_{v}) l^6\}$$

$$B = 4l \sin\theta\{A^2_{,}(Q'_{,} Q''_{,} \sin^2\theta - Q'^2_{,} \cos\theta) + A^2_{,,,}(Q'_{,,,} Q''_{,,,} \sin^2\theta - Q'^2_{,,,} \cos\theta)\frac{l^4}{5} + A_{v}(Q'_{v} Q''_{v} \sin^2\theta - Q'_{v} \cos\theta)\frac{l^8}{9} + A_{,} A_{,,,}\Big((Q'_{,} Q''_{,,,} + Q''_{,} Q'_{,,,}) \sin^2\theta - 2Q'_{,} Q'_{,,,} \cos\theta\Big)\frac{l^2}{3} + A_{,} A_{v}\Big((Q'_{,} Q''_{v} + Q''_{,} Q'_{v}) \sin^2\theta - 2Q'_{,} Q'_{v} \cos\theta\Big)\frac{l^4}{5} + A_{,,,} A_{v}\Big((Q'_{,,,} Q''_{v} + Q''_{,,,} Q'_{v}) \sin^2\theta - 2Q'_{,,,} Q'_{v} \cos\theta\Big)\frac{l^6}{7}\}$$

$$C = +4l\{A^2_{,}\big((Q_{,} Q''_{,} + Q'^2_{,}) \sin^2\theta - Q_{,} Q'_{,} \cos\theta\big) + 3A^2_{,,,}\Big((Q_{,,,} Q''_{,,,} + Q'^2_{,,,}) \sin^2\theta - Q_{,,,} Q'_{,,,} \cos\theta\Big)\frac{l^4}{5} + 5A^2_{v}\Big((Q_{v} Q''_{v} - Q'^2_{v}) \sin^2\theta - Q_{v} Q'_{v} \cos\theta\Big)\frac{l^8}{9} + A_{,} A_{,,,}\Big((3Q'_{,} Q'_{,,,} + 3Q''_{,} Q_{,,,} + Q'_{,} Q'_{,,,} + Q_{,} Q''_{,,,}) \sin^2\theta$$

$$- (3Q'_{,} Q_{,,,} + Q_{,} Q'_{,,,}) \cos\theta\Big)\frac{l^2}{3} + A_{,} A_{v}\Big((5Q'_{,} Q'_{v} + 5Q''_{,} Q_{v} + Q'_{,} Q'_{v} + Q_{,} Q''_{v})\sin^2\theta - (5Q'_{,} Q_{v} + Q_{,} Q'_{v})\cos\theta\Big)\frac{l^4}{5} + A_{,,,} A_{v}\Big((5Q''_{,,,} Q_{v} + 5Q'_{,,,} Q'_{v} + 3Q'_{,,,} Q'_{v} + 3Q_{,,,} Q''_{v})\sin^2\theta - (5Q'_{,,,} Q_{v} + 3Q_{,,,} Q'_{v})\cos\theta\Big)\frac{l^6}{9}\Big\}$$

Where

$$\begin{aligned}
Q_{,} &= \cos\theta \\
Q_{,,,} &= \tfrac{1}{2}(5\cos^3\theta - 3\cos\theta) \\
Q_{v} &= \tfrac{1}{8}(63\cos^5\theta - 70\cos^3\theta + 15\cos\theta) \\
Q'_{,} &= 1 \\
Q'_{,,,} &= \tfrac{3}{2}(5\cos^2\theta - 1) \\
Q'_{v} &= \tfrac{15}{8}(21\cos^4\theta - 14\cos^2\theta + 1) \\
Q''_{,} &= 0 \\
Q''_{,,,} &= 15\cos\theta \\
Q''_{v} &= \tfrac{15}{2}(21\cos^3\theta - 7\cos\theta) \\
\mu &= \cos\theta
\end{aligned}$$

$$A = 4l\sin\theta\Big\{\big(A_{,}^2 + \tfrac{81}{20}A_{,,,}^2 l^4 + \tfrac{18375}{192}A_{v}^2 l^8 - 3A_{,}A_{,,,} l^2 + \tfrac{15}{4}A_{,}A_{v} l^4 - \tfrac{675}{56}A_{,,,}A_{v} l^6\big)\mu + \big(-27A_{,,,}^2 l^4 - \tfrac{4375}{24}A_{v}^2 l^8 + 10A_{,}A_{,,,} l^2 - 35A_{,}A_{v} l^4 + \tfrac{42875}{28}A_{,,,}A_{v} l^6\big)\mu^3 + \big(\tfrac{135}{4}A_{,,,}^2 l^4 + \tfrac{56625}{64}A_{v}^2 l^8 + \tfrac{189}{4}A_{,}A_{v} l^4 - \tfrac{34655}{8}A_{,,,}A_{v} l^6\big)\mu^5 + \big(-\tfrac{61125}{4}A_{v}^2 l^8 + \tfrac{675}{2}A_{,,,}A_{v} l^6\big)\mu^7 + \tfrac{55125}{64}A_{v}^2 l^8\mu^9\Big\}$$

$$B = 4l\sin\theta\Big\{\big(-A_{,}^2 - \tfrac{99}{20}A_{,,,}^2 l^4 - \tfrac{725}{64}A_{v}^2 l^8 + 6A_{,}A_{,,,} l^2 - \tfrac{45}{4}A_{,}A_{v} l^4 + \tfrac{225}{14}A_{,,,}A_{v} l^6\big)\mu + \big(\tfrac{63}{2}A_{,,,}^2 l^4 - \tfrac{1575}{16}A_{v} l^8 - 10A_{,}A_{,,,} l^2 + \tfrac{171}{4}A_{,}A_{v} l^4 - \tfrac{2475}{14}A_{,,,}A_{v} l^6\big)\mu^3 + \big(-\tfrac{135}{4}A_{,,,}^2 l^4 - \tfrac{16275}{32}A_{v}^2 l^8 - \tfrac{189}{4}A_{,}A_{v} l^4 + \tfrac{945}{2}A_{,,,}A_{v} l^6\big)\mu^5 + \big(\tfrac{77425}{48}A_{v}^2 l^8 - \tfrac{675}{2}A_{,,,}A_{v} l^6\big)\mu^7 + \tfrac{55125}{64}A_{v} l^8\mu^9\Big\}$$

$$C = 4l\Big\{\big(-A_{,}^2 - \tfrac{125}{64}A_{v}^2 l^8 - \tfrac{1}{2}A_{,}A_{,,,} l^2 + \tfrac{3}{40}A_{,}A_{v} l^4 - \tfrac{5}{2}A_{,,,}A_{v} l^6\big) + \big(-\tfrac{3}{2}A_{,}A_{,,,} l^2\big)\mu + \big(-\tfrac{297}{20}A_{,,,}^2 l^4 - 6A_{,}A_{,,,} l^2 - \tfrac{7}{2}A_{,}A_{v} l^4 + \tfrac{855}{8}A_{,,,}A_{v} l^6\big)\mu^2 + 9A_{,}A_{,,,} l^2\mu^3 + \big(45A_{,,,}^2 l^4 + \tfrac{72625}{96}A_{v}^2 l^8 + \tfrac{5}{2}A_{,}A_{,,,} l^2 + \tfrac{511}{4}A_{,}A_{v} l^4 - \tfrac{6485}{12}A_{,,,}A_{v} l^6\big)\mu^4 - \tfrac{15}{2}A_{,}A_{,,,} l^2\mu^5 + \big(-\tfrac{99}{4}A_{,,,}^2 l^4 - \tfrac{17975}{24}A_{v}^2 l^8 - \tfrac{441}{5}A_{,}A_{v} l^4 + \tfrac{24815}{48}A_{,,,}A_{v} l^6\big)\mu^6 + \big(\tfrac{54125}{192}A_{v}^2 l^8 - \tfrac{7875}{1}A_{,,,}A_{v} l^6\big)\mu^8\Big\}$$

Or we can write

$$\begin{aligned}
A &= 4l\sin\theta\{L\mu + L'\mu^3 + L''\mu^5 + \text{etc.}\} \\
B &= 4l\sin\theta\{M\mu + M'\mu^3 + \text{etc.}\} \\
C &= 2l\{N + N'\mu + N''\mu^2\ \text{etc.}\}
\end{aligned}$$

where the values of L, M, etc. are apparent.

To sum up we may then write as before

$$\Theta = -\tfrac{1}{2}a\{A[(k_1 - k_2)\alpha^2 + k_2] + B[(k_1 - k_2)\alpha'^2 + k_2] - C(k_1 - k_2)\alpha\alpha'\}$$

where A, B and C are the quantities we have found, a is the cosine of the angle made by the axis of the crystal with the axis of the bar, and α' is the cosine of the angle made by the same axis with a horizontal line at right angles to the bar.

The equation

$$\Theta = 0$$

gives equilibrium at some angle depending on a and α', and if either of these is zero the angle can be either $\theta = 0$ or $\frac{1}{2}\pi$, one of which will be stable and the other unstable according as the body is para- or dia-magnetic.

For a diamagnetic crystal like bismuth with the axis at right angles to the bar we can put

$$\mu = \cos\theta = \sin\psi \text{ and } \alpha = 0,$$

and we can write

$$\Theta = -\tfrac{1}{2}a\{4lk_2(\mathrm{L}\mu + \mathrm{L}\mu'^2 + \text{etc.}) + 4l[(k_1 - k_2)\alpha'^2 + k_2][\mathrm{M}\mu + \mathrm{M}'\mu^2 + \text{etc.}]\}$$

or for very small values of μ we can write in terms of ψ

$$\Theta = -2al\psi\{k_2\mathrm{L} + \big((k_1 - k_2)\,\alpha'^2 + k_2\big)\,\mathrm{M}\}$$

If I is the moment of inertia of the bar and t is the time of a single vibration, we may write

$$\Theta = \mathrm{I}\frac{\pi^2}{t^2}\,\psi.$$

If we hang up the bar so that $\alpha' = 0$ we have

$$k_2(\mathrm{L} + \mathrm{M}) = -\frac{\pi^2\,\mathrm{I}}{2alt^2}$$

and if we hang it up so that $\alpha' = \frac{1}{2}\pi$ we have again

$$k_2\,\mathrm{L} + k_1\,\mathrm{M} = -\frac{\pi^2\,\mathrm{I}'}{2alt'^2}$$

whence

$$k_2 = -\frac{\pi^2\,\mathrm{I}}{2alt_2} \cdot \frac{1}{\mathrm{L} + \mathrm{M}}$$

$$k_1 = -\frac{1}{\mathrm{M}}\left(\frac{\pi^2\,\mathrm{I}'}{2alt'^2} + k_2\,\mathrm{L}\right)$$

where

$$\mathrm{L} = \mathrm{A}^2_{,} - 3\mathrm{A}_{,}\mathrm{A}_{,,,}l^2 + (\tfrac{81}{20}\mathrm{A}^2_{,,,} + \tfrac{15}{4}\mathrm{A}_{,}\mathrm{A}_{\mathrm{v}})\,l^4 - \tfrac{675}{56}\mathrm{A}_{,,,}\mathrm{A}_{\mathrm{v}}l^6 + \tfrac{1875}{192}\mathrm{A}^2_{\mathrm{v}}\,l^8$$
$$\mathrm{M} = -\mathrm{A}^2_{,} + 6\mathrm{A}_{,}\mathrm{A}_{,,,}l^2 - (\tfrac{99}{20}\mathrm{A}^2_{,,,} + \tfrac{45}{4}\mathrm{A}_{,}\mathrm{A}_{\mathrm{v}})l^4 + \tfrac{225}{14}\mathrm{A}_{,,,}\mathrm{A}_{\mathrm{v}}\,l^6 - \tfrac{725}{64}\mathrm{A}^2_{\mathrm{v}}l^8$$
$$\mathrm{L} + \mathrm{M} = 3\mathrm{A}_{,}\,\mathrm{A}_{,,,}\,l^2 - (\tfrac{9}{10}\,\mathrm{A}^2_{,,,} + \tfrac{15}{2}\mathrm{A}_{,}\,\mathrm{A}_{\mathrm{v}})\,l^4 + \tfrac{225}{56}\mathrm{A}_{,,,}\,\mathrm{A}_{\mathrm{v}}l^6 - \tfrac{75}{48}\,\mathrm{A}^2_{\mathrm{v}}\,l^8$$

For a cleavage bar of calc spar we must use the general equation. For equilibrium we have

$$k_1\{\mathrm{A}\alpha^2 + \mathrm{B}\alpha'^2 - \mathrm{C}\alpha\alpha'\} + k_2\{\mathrm{A}\,(1 - \alpha^2) + \mathrm{B}\,(1 - \alpha'^2) + \mathrm{C}\alpha\alpha'\} = 0$$

which gives us the ratio of k_1 to k_2. For this experiment it is best to hang up the bar so that the axis is in the horizontal plane and we should then have

$$\alpha^2 = 1 - \alpha'^2$$

For obtaining another relation it is best to suspend the bar with $\alpha'=0$ and we then have the position of stable equilibrium at the point $\theta=\frac{1}{2}\pi$, which gives

$$\Theta = -2al\psi\{L[(k_1-k_2)\alpha^2+k_2]+Mk_2\} = \frac{\pi^2 I}{t^2}\psi,$$

whence

$$k_1 = -\frac{\pi^2 I}{2alt^2}\frac{1}{L\left[\left(1-\frac{k_2}{k_1}\right)\alpha^2+\frac{k_2}{k_1}\right]+M\frac{k_2}{k_1}}$$

these various equations give the complete solution of the problem of finding the various coefficients of magnetization.

PART II.—By WILLIAM W. JACQUES, Fellow in Physics of the Johns Hopkins University.

IN the foregoing part of this paper there have been deduced mathematical expressions for the constants k and k' both for bismuth and for calc-spar crystals. In these expressions it is necessary to substitute certain quantities obtained by a series of experiments, and it is the purpose of the remaining portion of the paper to describe briefly the way in which these quantities were obtained.

These experiments are naturally divided into two parts. First, the exploration of the small magnetic field between the two poles of the electromagnet, and second, the determination of the time of swing and certain other constants relating to little bars of the substances experimented upon when suspended in this field.

In order to insure the constancy of the magnetic field, a galvanometer and variable resistance were inserted in the circuit through which the magnetizing current circulated. This space between the poles of the electromagnet in which the experiments were performed was a little larger than a hen's egg. The method of exploring this field was as follows: In the line joining the centers of the two poles was placed a little brass rod, along which a very small coil of fine wire was made to slide. To this rod were fixed two little set-screws to regulate the distance through which the coil could be moved. Starting now always from the center, the coil was moved successively through distances a, b and c, and the corresponding deflections of a delicate mirror galvanometer contained in the circuit were noted. To each of these deflections was added the deflection due to quickly pulling the coil away from the center

to a distance such that the magnetic potential was negligably small. Of course, experiments were made on both sides of the center of the field in order to eliminate any want of symmetry, and the distances through which the coil moved were all carefully measured with a dividing engine.

In order to reduce the deflections of the galvanometer to absolute measure, an earth inductor was included in the circuit with the little coil and galvanometer and the deflections produced by this were compared with those produced by moving the little coil. These deflections were taken between every two observations with the little coil.

The deflections due to moving the little coil, those due to the earth inductor and that due to pulling the coil away from the center are given in the following table:

	Distance *a*.	Distance *b*.	Distance *c*.
Coil	$4·407^{cm}$	$9·655^{cm}$	$6·363^{cm}$
Earth inductor	$33·138^{cm}$	$33·137^{cm}$	$33·162^{cm}$
Drawing coil away from center			$57·416^{cm}$

In order to determine the proper quantities for substitution in the expression for the magnetic potential of the field, it was necessary to measure, besides the deflections due to the little coil when moved through various distances and those due to the earth inductor.

The mean radius of the small coil	$= ·3912^{cm}$
Number of turns	$= 83·$
Width of coil	$= ·1824^{cm}$
Depth of coil	$= ·1212^{cm}$
Integral area of earth inductor	$= 20716·2^{cm}$
Horizontal intensity of earth's magnetism	$= ·1984^{cgs}$

The quotient of the mean radius of the coil by the distance moved gave tan θ.

The linear measurements were made with a dividing engine.

The horizontal intensity of the earth's magnetism was determined by measuring the time of swing of a bar magnet and its effect upon a smaller galvanometer needle. The proper substitution of these quantities in the formula given gave the expression in absolute measure for the magnetic potential at any part of the field.

The remaining part of the experiment and the part that was attended with greatest difficulty, was to prepare little bars of the substances and to determine the times of vibration of these when suspended, first with the axis vertical and then with it horizontal in the magnetic field. Besides this, the dimensions and the moment of inertia of each bar had to be determined, and, in the case of the calc-spar, the angle the bar made with the equatorial line of the poles when in its position of equilibrium, had to be measured.

Bismuth and calc-spar were the two crystals experimented upon; quite a number of other substances were tried but failed to give good results because of the iron contained in them as an impurity. The bars were each about 15^{mm} long and about 2^{mm} in cross section. The force to be measured being only about ·00000001 of that exerted in the case of iron it was necessary to carry out the experiments with the very greatest care.

In order to obtain bars free from iron, very fine crystals of chemically pure substances were selected and the bars cleaved from them. They were then polished with their various sides parallel to the cleavage planes by rubbing on clean plates of steatite with oil. In order to remove any particles of iron that might have collected upon them during these processes, they were carefully washed with boiling hydrochloric acid and with distilled water and then wrapped in clean papers, and never touched except after washing the hands with hydrochloric acid and distilled water.

In order to reduce to a minimum the causes that might interfere with the accurate determination of the times of vibration of these bars the poles of the magnet were encased by a box of glass. From the top of this a tube four feet long extended up toward the ceiling, and inside this was hung a single fiber of silk so small as to be barely visible to the naked eye. The bars were placed in little slings of coarser silk fiber and suspended by this. Outside the glass case was a microscope placed horizontally and having a focus of about six inches. This was directed toward the suspended bar, and when the latter was at rest the cross hairs of the microscope fell upon a little scratch in one end of the bar. Near by was a telegraph sounder arranged to tick seconds. The bar was set swinging through a small arc by making and breaking the current, and the interval between two successive transits of the little scratch on the bar by the cross hairs of the microscope was measured in seconds and tenths of a second by the ear. By keeping count through a large number of successive transits the time of a single swing could be determined with very great accuracy. The bar was caused to swing only through a few degrees of arc and such small correction for amplitude as was found necessary was applied. The time of swing was determined first with the axis vertical and then with it horizontal. But besides the time of swing of each bar it was necessary to measure: the length; area of section; moment of inertia in each position; and for the calc-spar bar the angle it made with the equatorial plane of the magnet when in its position of equilibrium. This was not necessary in the case of bismuth, because its position of equilibrium lay in the equatorial plane.

Bismuth.

	Time of swing.	Moment of inertia.	Half length.	Area of section.
Axis, vertical	$7{\cdot}18^{sec}$	$\cdot10976^{cgs}$	$\cdot7709^{cm}$	$\cdot03778^{cm}$
Axis, horizontal, ..	$5{\cdot}76^{sec}$	$\cdot10943^{cgs}$		

Calc-Spar.

	Time of swing.	Moment of inertia.	Half length.	Area of section.	α
Axis, vertical	$46{\cdot}35^{sec}$	$\cdot0303^{cgs}$	$\cdot8015^{cm}$	$\cdot0300^{cm}$	$50°\ 30'$
Axis, horizontal ...	$43{\cdot}39^{sec}$	$\cdot0300^{cgs}$			

The linear measurements were made with a dividing engine, the moments of inertia were calculated from the dimensions of the bars. The angle at which the calc-spar stood was measured by projecting the linear axis on a scale placed at a distance.

The above quantities being all determined and properly substituted, the solution of the equations gave for

Bismuth .... $k_{\prime} = -\ {\cdot}000\ 000\ 012\ 554$
$k_{\prime\prime} = -\ {\cdot}000\ 000\ 014\ 324$
Calc-spar .... $k_{\prime} = -\ {\cdot}000\ 000\ 037\ 930$
$k_{\prime\prime} = -\ {\cdot}000\ 000\ 040\ 330$

ART. XLIII.—*On the Vapor-Densities of Peroxide of Nitrogen, Formic Acid, Acetic Acid, and Perchloride of Phosphorus;* by J. WILLARD GIBBS.

[Continued from page 293.]

Acetic acid.—For this substance the densities have been calculated by the formula

$$\log \frac{2{\cdot}073\,(D - 2{\cdot}073)}{(4{\cdot}146 - D)^2} = \frac{3520}{t_C + 273} + \log p - 11{\cdot}349, \qquad (12)$$

the constants 3520 and 11·349 being derived from the determinations of Cahours and Bineau, which with those of Horstmann and Troost are given in Table IV. The experiments of Cahours and Horstmann were made under atmospheric pressure, those of Horstmann* by the method of Bunsen, those of Cahours presumably by the method of Dumas. The numbers in the first column of the densities observed by Cahours are taken from the twentieth volume (1845) of the Comptes Rendus, except a few cases, distinguished by parentheses, which are taken from the preceding volume (1844). The numbers in the second column are taken from his Leçons de chimie générale élémentaire, 1856. These numbers seem to be based in part

* Lieb. Ann., Suppl. VI, p. 65.

Table IV.—Acetic Acid.

Experiments of Cahours,—Horstmann,—Bineau,—Troost.

Temperature.	Pressure.	Density calc. by eq. (12).	Density observed. Cahours. C. B.	Density observed. Cahours. Legons.	Density observed. Horstmann.	Excess of observed density. Cahours. C. B.	Excess of observed density. Cahours. Legons.	Excess of observed density. Horstmann.
338	(760)	2·077	2·08			·00		
336	(760)	2·077		2·082			+ ·005	
327	(760)	2·078	2·08	2·085		·00	+ ·007	
321	(760)	2·079	2·08	2·083		·00	+ ·004	
308	(760)	2·081		2·085			+ ·004	
300	(760)	[illegible]	[illegible]			·00		
295	(760)	2·084		[illegible]			— ·001	
280	(760)	2·089	[illegible]			— ·01		
272	(760)	[illegible]		2·088			— ·005	
264·6	747·2	2·105			2·135			+ ·030
252	(760)	2·108		2·090			— ·018	
250	(760)	2·111	2·08			— ·03		
240	(760)	2·122		2·090			— ·032	
[illegible]	752·8	2·132			2·195			+ ·063
231	(760)	2·137	(2 12)	2·101		(— ·02)	— ·036	
230	(760)	2·139	2·09			— ·06		
219	(760)	2·165	2·17	2 132		+ ·01	— ·033	
200	(760)	[illegible]	2·22	2·246		— ·02	+ ·009	
190	(760)	2·298	2·30	2·378		·00	+ ·080	
181·7	749·7	[illegible]			2·419			+ ·060
180	(760)	[illegible]		2·438			+ ·062	
171	(760)	[illegible]	2·42			— ·05		
170	(760)	2·477		2·480			+ ·003	
165·0	754·1	[illegible]			2·647			+ ·113
162	(760)	2·575		[illegible]			+ ·008	
160·3	751·6	2·594			2·649			+ ·055
160	(760)	2·601	2·48			— ·12		
152	(760)	2·716	(2·72)	2·727		(·00)	+ ·011	
150	(760)	2·747	2·75			·00		
145	(760)	2·826	(2·75)			(— ·08)		
[illegible]	(760)	2 910	2·90	2·907		— ·01	— ·003	
134·3	748·8	3·001			3·108			+ ·107
131 3	754·1	3·055			3·070			+ ·015
130	(760)	3·082	3·12	3·105		+ ·04	+ ·023	
128·6	752·9	3 103			3·079			— ·024
125	(760)	3 168	3·20			+ ·03		
124	(760)	3·185		3·194			+ ·009	
			Bineau.		Troost.	Bineau.		Troost.
132	757	3·05	(2·86)			(— ·19)		
130	69·7	2 31			2·12			— ·19
130	30 6	2·21			2·10			— ·11
129	633	3·03	(2·88)			(— ·15)		
36·5	11·32	3·63	3·62			— ·01		
35·0	11·19	3·65	3·64			— ·01		
30·0	6·03	3·61	3·60			— ·01		
[illegible]	10·03	3·75	3·75			·00		
24·0	5 75	3·71	3·70			— ·01		
22·0	8·64	3·82	3·85			+ ·03		
22	2·70	3·59	3·56			— ·[illegible]		
21 0	4·06	3·70	3 72			+ ·02		
20·5	10·03	3·86	3·95			+ ·09		
20·0	8·55	3·84	3 88			+ ·04		
20·0	5·56	3·77	3·77			·00		
19·0	4·00	3·73	3·75			+ ·02		
19	2·60	3·65	3·66			+ ·01		
12·0	5 23	3·88	3·92			+ ·04		
12	2·44	3·77	3·80			+ ·03		
11·5	3·76	3·84	3·88			+ ·04		

upon new experiments and in part upon a revision of the observations recorded in the Comptes Rendus, the calculations being carried out to another figure of decimals. They are therefore entitled to a greater weight than the numbers of the preceding column.

The agreement of the formula with the numbers given in the Leçons de chimie is very good, the greatest divergences being ·080 at 190° and ·062 at 180°. But at 190° the table in the Comptes Rendus agrees precisely with the formula, and at 171° (the next experiment) it shows a divergence in the opposite direction. The next divergences in the order of magnitude are —·033, —·036, —·032 at 219°, 231°, 240°, respectively. Here the table in the Comptes Rendus agrees substantially with that of the Leçons, but the experiments of Horstmann show a divergence to the opposite direction. In fact, the three columns of observed densities nowhere agree in the direction of their divergence from the formula.

The somewhat decided differences between the results of Horstmann and those of Cahours may be due in part to the different methods of observation, especially to the entirely different manner of applying the heat and measuring the temperature. But the higher values obtained by Horstmann cannot be accounted for by too short an exposure to the source of heat, for his experiments were made with decreasing temperatures.

The determination of Bineau are taken from the same sources as those on formic acid, the earlier determinations being distinguished as before by parentheses. One of these (at 132°) was made by the method of Dumas, the other by that of Gay-Lussac. The smallness of the observed densities appears due to the presence of water. (An acidimetric test gave 295 parts of acid in 306.) The other experiments were made with the same apparatus which was used with formic acid and show even greater regularity in their results than the experiments with that substance. Only in one case is the influence of proximity to saturation seen, viz., at 20·5° and 10·03^{mm}, the pressure of saturated vapor at this temperature being about 12·7^{mm}.* In the remaining fifteen observations of this series, notwithstanding the very low pressures employed (from 2·44 to 11·32), the greatest difference between the observations and the formula is ·04, and the average difference ·02.

The two observations by Troost† were made by the method of Dumas, but at pressures very low for this method. The results obtained differ considerably from the formula, but not so much as in the case of his experiments at low pressure with peroxide of nitrogen.

* This number is obtained from data given by Bineau by the same kind of interpolation which was used for formic acid.

† Comptes Rendus, vol. lxxxvi (1878), p. 1395.

Table V contains the experiments of Naumann* on acetic acid. These consist of ten series (distinguished by the letters

TABLE V.—ACETIC ACID.

Experiments of NAUMANN.

		Temperature.								
		78°	100°	110°	120°	130°	140°	150°	160°	185°
A	Pressure.		393·5	411	432	455	477	498·5		565
	D. calc.		3·39	3·23	3·06	2·90	2·75	2·61		2·28
	D. obs.		3·44	3·31	3·14	2·97	2·82	2·68		2·36
	Exc. of D. obs.		+·05	+·08	+·08	+·07	+·07	+·07		+·08
B	Pressure.		342·3	359·3	377·5	398·5	417·5	436·5		495
	D. calc.		3·35	3·18	3·02	2·85	2·70	2·57		2·26
	D. obs.		3·37	3·22	3·06	2·89	2·75	2·63		2·31
	Exc. of D. obs.		+·02	+·04	+·04	+·04	+·05	+·06		+·05
C	Pressure.		258							382
	D. calc.		3·26							2·22
	D. obs.		3·17							2·25
	Exc. of D. obs.		—·09							+·03
D	Pressure.		232		252	274	287·5	300		335
	D. calc.		3·23		2·87	2·72	2·58	2·46		2·21
	D. obs.		3·12		2·94	2·68	2·54	2·44		2·23
	Exc. of D. obs.		—·11		+·07	—·04	—·04	—·02		+·02
E	Pressure.	164	186	197	209	221	232	243	253	269
	D. calc.	3·53	3·15	2·97	2·81	2·65	2·52	2·41	2·32	2·18
	D. obs.	3·41	3·06	2·91	2·75	2·61	2·50	2·40	2·31	2·22
	Exc. of D. obs.	—·12	—·09	—·06	—·06	—·04	—·02	—·01	—·01	+·04
F	Pressure.	149	168			201				
	D. calc.	3·50	3·12			2·62				
	D. obs.	3·34	3·01			2·56				
	Exc. of D. obs.	—·16	—·11			—·06				
G	Pressure.	137	156	166·5	180	188	199	208·2		230
	D. calc.	3·48	3·09	2·92	2·75	2·60	2·47	2·37		2·17
	D. obs.	3·26	2·98	2·81	2·61	2·50	2·40	2·29		2·14
	Exc. of D. obs.	—·22	—·11	—·11	—·14	—·10	—·07	—·08		—·03
H	Pressure.	113	130	138·5	149	157·5	168·2	175		191·5
	D. calc.	3·42	3·03	2·85	2·69	2·55	2·43	2·33		2·15
	D. obs.	3·25	2·94	2·78	2·60	2·47	2·32	2·26		2·13
	Exc. of D. obs.	—·17	—·09	—·07	—·09	—·08	—·11	—·07		—·02
J	Pressure.	80	92	98·5	106	112·5	117·3		129·2	
	D. calc.	3·32	2·91	2·73	2·58	2·45	2·35		2·21	
	D. obs.	3·06	2·76	2·61	2·46	2·34	2·27		2·11	
	Exc. of D. obs.	—·26	—·15	—·12	—·12	—·11	—·08		—·10	
K	Pressure.	66	77·7	84	89·5	93	98	103		110·5
	D. calc.	3·26	2·85	2·68	2·53	2·40	2·31	2·24		2·12
	D. obs.	3·04	2·66	2·49	2·37	2·32	2·24	2·16		2·11
	Exc. of D. obs.	—·22	—·19	—·19	—·16	—·08	—·07	—·08		—·01

A, B, C, etc.) of observations by Hoffmann's method.† The temperatures of the observations in the different series are for

* Lieb. Ann., vol. clv, S. 325.

† This is a modification of the method of Gay-Lussac, in which the heat is supplied by a vapor bath.

the most part the same, so that for each temperature we have observations through a wide range of pressures. Within each compartment of the table are given in order the pressure of an experiment, the density calculated by equation (12), the observed density, and the excess of observed density, the temperature of the experiment being given at the head of the column. These experiments, taken by themselves, seem to show an effect of pressure upon the density about one third greater than is indicated by the formula. But the divergences (of which the greatest is ·26 and the average ·085), are not large in view of the fact that the experiments were undertaken rather with the desire of obtaining a great number of observations with moderate labor, than with the intention of attaining the greatest possible accuracy.

The quantity of acid diminishes somewhat regularly from ·2084 grams in series A to ·0185 in series K. The volume, which was 154^{cc} in the experiment at 185° in series A, diminishes in the successive series, and in the same series with diminishing temperature, to 69·6^{cc} in the experiment at 78° in series K. It is worthy of notice that the greatest deviations from the formula occur where the liability to error is most serious with respect to pressure (which was measured without a cathetometer), to volume, and to the quantity of acid.

Far more serious than the absolute amount of these divergences, is the regularity which they exhibit. But it must be remembered that the observations are by no means entirely independent, and many sources of possible error, such as the calibration of the tube and the determination of the quantity of acid, might affect the results with considerable regularity.

Only to a slight degree can the divergences from the formula be accounted for by an insufficient exposure to the temperature of the experiment. The observations, except those at 78°, were made with increasing temperatures, and the greatest divergences from the formula are not in the positive direction. Yet the positive divergences occur where we should most expect to find them, if they were due to this cause, viz., in the series in which the greatest quantities of acid were used, and in cases in which the temperature seems to have been raised at once an unusual number of degrees. (See especially the observation at 120° in series D, and in general the observations at 185°, which exhibit if not a positive at least a diminution of negative excess.) In the observations at 78°, which were the last of each series, and therefore followed a fall of temperature from 185°, we find in some cases, especially in series G, H, and J, a negative divergence much greater than in the other determinations of the same series, and which appears to be referable to this circumstance.

In Table VI are exhibited the results of experiments by Playfair and Wanklyn,* in which the vapor of the acid was diluted with hydrogen or, in a single case (the experiment at 95·5°), by air. Columns I and II of the observed densities relate each to a series of observations by the method of Gay-Lussac, column III contains four independent determinations by the method of Dumas. The numbers in the column of pressures are, as in other similar cases, the partial pressures obtained by subtracting from the total pressure (which was never very much less than that of the atmosphere) that which would be exerted by the hydrogen or air alone.

TABLE VI.—ACETIC ACID.

Experiments of PLAYFAIR and WANKLYN.

Temperature.	Pressure.	Density calc. by eq. (12).	Density observed. I.	II.	III.	Excess of observed density. I.	II.	III.
212·5	322·8	2·124		2·060			—·064	
194	326·0	2·168		2·055			—·113	
186	254·4	2·173	1·936			—·237		
182	319·4	2·213		2·108			—·105	
166·5	289·5	2·293		2·350			+·057	
163	245·8	2·290	2·017			—·273		
132	227·5	2·628	2·292			—·336		
130·5	285·7	2·729		2·426			—·303	
119	269·0	2·914		2·623			—·291	
116·5	211·3	2·876	2·371			—·505		
95·5	(123·8)	3·105			2·594			—·511
86·5	(200·4)	3·432			3·172			—·260
79·9	(83·3)	3·297			3·340			+·043
62·5	(46·2)	3·473			3·950			+·477

The first observation of the first series gives the density 1·936, which is doubtless too small, since it is much less than the theoretical limit 2·073. Since the greater part of the measurements from which this number was calculated, were also used in reducing the other observations of the series, the error probably affects the other observations, and in a somewhat increased degree. This will account only for a part of the difference between the observations and the formula. The remaining part of the differences in this series, and the somewhat smaller differences in the next, may be due to the fact that the experiments of both series were conducted with descending temperatures. Yet the experiments of the third column, which were made by Dumas' method, do not exhibit any preponderance of positive values for the excess of observed density, but rather the opposite.

On the whole, these experiments furnish no decisive indication of any influence of the hydrogen or air upon the vapor.

* Trans. Roy. Soc. Edinb., vol. xxii, p. 455.

They may be thought to corroborate slightly the tendency observed in the experiments of Naumann and Troost toward lower densities than the formula gives at very low pressures. Yet where the experiments of Naumann show the greatest deficiency in observed density (at 78° and 80^{mm}), an experiment of Playfair and Wanklyn, at almost precisely the same temperature and pressure, gives a trifling excess of observed density, and at a little lower temperature and pressure, where we should expect from the experiments of Naumann that the deficiency would be still greater, an experiment of Playfair and Wanklyn shows a great excess of density.

By combining the experiments of Cahours, Naumann and Troost, we may obtain observations of density at 130° for a very wide range of pressures. For one atmosphere, we may regard the formula as coinciding with the average of the numbers given by Cahours. For pressures between three-quarters and one-half of an atmosphere the experiments of Naumann show an excess of density; at pressures below half an atmosphere the experiments both of Naumann and of Troost show a deficiency of density as compared with the formula. For an indefinite diminution of pressure, there can be little doubt that the real density, like the value given by the formula, approaches the theoretical value 2·073. The greatest excess in the numbers obtained by experiment is ·07; the greatest deficiency is ·19, which occurs at $59{\cdot}7^{mm}$; the next in order of magnitude is ·11, which occurs more than once. These discrepancies are certainly such as may be accounted for by errors of observation. They do not appear to be greater than we might expect on the hypothesis of the entire correctness of the formula. On the other hand, the agreement is greater than we should expect, if we reject the theory on which the formula was obtained. It is about such as we might expect in a suitable formula of interpolation with three constants, which have been determined by the values of the density for one atmosphere, for half an atmosphere, and for infinitesimal pressures. But we must regard the actual formula, in its application to this single temperature, as having only two constants, of which one is determined so as to make the formula give the theoretical value for infinitesimal pressures, and the other so as to make it agree with the experiments of Cahours at the pressure of one atmosphere.

An entirely different method has been employed by Horstmann* to determine the vapor-density of this substance. A current of dried air is forced through the liquid acid, which is heated to promote evaporation, and the mixture of air and vapor is

* Berichte der deutschen chemischen Gesellschaft, Jahrg. iii (1870), S. 78; and Jahrg. xi (1878), S. 1287.

cooled to any desired temperature, with deposition of the excess of acid, by passing upward through a spiral tube in a suitable bath. The acid is then separated from the air, and the quantity of each determined. It is assumed that the air is exactly saturated with vapor on leaving the coil, and that it has the temperature of the bath. If we know the pressure of saturated vapor for that temperature, and assume the validity of Dalton's law, it is easy to calculate the density of the vapor. For the pressure of the air is found by subtracting the pressure of the vapor from the total pressure, (the experiments were so conducted that this was the same as the actual pressure of the atmosphere,) and the ratio of the weights of the acid and the air obtained by analysis, divided by the ratio of their pressures, will give the ratio of their densities. The pressures of saturated vapor employed by Horstmann are those given by Landolt,* and differ greatly from the determinations of Regnault, in some cases being nearly twice as great,—a difference noticed but not explained by Landolt, who however gives determinations (previously unpublished) of Wüllner, which somewhat exceed his own. (On the other hand, the observations of Bineau substantially agree with those of Regnault.)

If we compare the observations of Horstmann with the values given by equation (12), on the basis of Landolt's pressures, we find a very marked disagreement, as may be seen by the following numbers, which relate to the highest temperatures of Horstmann's experiments, where the disagreement is least.

Temperature	63·1	62·9	59·9	51·1	49·0	48·7	44·6	41·4
Pressure (Land.)	110·0	109·2	97·0	69·0	63·4	63·0	53·1	46·6
Density calc. eq. (12)	3·67	3·67	3·69	3·75	3·77	3·77	3·79	3·81
Density obs.	3·19	3·11	3·12	3·16	2·89	2·98	2·75	2·62

It will be observed that while the values obtained from equation (12) increase with diminishing temperatures, the values obtained from Horstmann's experiments diminish. This diminution continues as far as the experiments go, until finally at 12° or 15° the densities are only one half as great as those obtained by Bineau, by direct experiment at the same temperatures and at somewhat less pressures, in a series of observations which bear every mark of a very exceptional precision. (Compare Tables VII and IV.) The explanation of this disagreement is doubtless to be found in the values of the pressures employed in the calculations, and it will be interesting to see how the results may be modified by the adoption of different pressures.

In determinations of the pressure of saturated vapors, too great values are so much more easily accounted for than errors in the opposite direction, especially when the pressures are small, that especial interest attaches to the lowest figures which

* Lieb. Ann., Suppl. vi (1868), p. 157.

are supported by a competent authority. The experiments of Regnault* were made with three different preparations of acetic acid, of which the second was once, and the third twice, purified by distillation over anhydrous phosphoric acid. Each distillation considerably diminished the pressure of the saturated vapor, the effect of the second distillation being about half that of the first. The numbers obtained with the third preparation are given in the following table with their logarithms, and the differences of the logarithms for one degree of temperature.

Temperature.	Pressure.	log. pressure.	diff. per 1°.
9·71	6·42	·8075	
			·0239
12·12	7·33	.8651	
			·0272
14·33	8·42	·9253	
			·0161
14·87	8·59	·9340	
			·0252
17·23	9·85	·9934	
			·0251
19·84	11·455	1·0590	
			·0237
22·37	13·15	1·1189	
			·0232
25·28	15·36	1·1864	

The uniformity of the numbers in the last column shows the remarkable precision of the determinations. At the same time it is evident that the differences in these numbers are due principally to the errors of observation, so that numbers obtained by interpolation between the logarithms of the observed pressures will be somewhat better (on account of averaging of the errors) than the original determinations.

The values obtained by such an interpolation have been used for the comparison of Horstmann's experiments with the formula (12) which is given in table VII. Unfortunately this comparison cannot be extended above 25°, which is the limit of Regnault's experiments. The first three columns of the table give the temperatures of Horstmann's experiments, the pressures corresponding to these temperatures according to the determinations of Landolt, and the density deduced from Horstmann's experiments by the use of these pressures. To these columns, which are taken from Horstmann's paper, are added the pressure derived from Regnault's observations by the logarithmic interpolation described above, the density calculated by equation (12) from these pressures and the temperatures of the first column, and the densities obtained by combining Horstmann's experiments with Regnault's pressures. This column is derived from the second, third and fourth, as follows. If w and W denote respectively the weights of vapor and of air which pass through the apparatus in the same time, P the height of the barometer, and p_L the pressure of saturated vapor as determined by Landolt, the densities obtained on the basis of Landolt's pressures, and given in the third column, are

* Mém. Acad. Sciences, vol. xxvi, p. 758. The experiments date from 1844.

evidently represented by $\frac{w(P-p_L)}{Wp_L}$. The numbers of the fifth column, which are represented in the same way by $\frac{w(P-p_R)}{Wp_R}$, where p_R denotes the pressure as determined by Regnault's experiments, have been calculated by the present writer by multiplying the numbers of the third column by $\frac{p_L(P-p_R)}{p_R(P-p_L)}$.

TABLE VII.—ACETIC ACID.

Determinations of Vapor-density by Distillation.

Temperature.	Pressure acc. to Landolt.	Density observed, Horstmann and Landolt.	Pressure acc. to Regnault.	Density calc. from Regnault's pressures by eq. (12).	Density observed, Horstmann & Regnault.	Excess of observed density. I.	II.
25·0	23·5	2·42	15·13	3·86	3·80	—·06	
23·8	22·4	2·23	14·19	3·86	3·56		—·30
22·6	21·6	2·29	13·31	3·87	3·76	—·11	
21·5	20·4	2·24	12·54	3·87	3·68	—·19	
20·4	19·2	2·05	11·81	3·88	3·37		—·51
20·2	19·0	2·28	11·68	3·88	3·75	—·13	
20·0	18·9	2·13	11·56	3·88	3·52		—·36
17·4	16·8	2·09	9·95	3·89	3·56	—·33	
15·6	15·6	1·98	8·96	3·90	3·48	—·42	
15·3	15·3	1·95	8·81	3·90	3·42		—·48
15·3	15·3	1·85	8·81	3·90	3·24		—·66
14·7	15·1	1·78	8·54	3·91	3·18	—·73	
12·7	13·7	1·96	7·60	3·91	3·56	—·35	
12·4	13·5	1·89	7·46	3·92	3·45	—·47	

As the height of the barometer in Horstmann's experiments is not given, it has been necessary to assume P=760. The inaccuracy due to this circumstance is evidently trifling. The last two columns of the table, which relate to different series of experiments by Horstmann (a distinction not observed in other parts of the table), give the excess of the densities thus obtained from Horstmann's and Regnault's experiments above the values calculated from equation (12) with the use of Regnault's determinations of pressure.

The densities obtained by experiment are without exception less than those obtained from equation (12). At the highest temperatures, where the liability to error is the least, both in respect to the measurement of the pressure of saturated vapor and in respect to the analysis of the product of distillation, the results of experiment are most uniform, and most nearly approach the numbers required by the formula. At the lowest temperatures, the greatest observed density is about one-eleventh less than that required by the formula, the difference being about the same as between the highest and lowest observed values for the same temperature.

Since each successive purification of the substance employed by Regnault diminished the pressure of its vapor, it is not improbable that the pressures might have been still farther diminished by farther purification of the substance. The pressures which we have used are therefore liable to the suspicion of being too high, and it is quite possible that more accurate values of the pressure would still farther reduce the deficiency of observed density.

Perchloride of phosphorus.—For this substance, we have at atmospheric pressure a single determination of vapor-density by Mitscherlich,* and a series of determinations by Cahours;† at lower pressures we have determinations by Wurtz‡ and by Troost and Hautefeuille.§ In the experiments of Wurtz the

TABLE VIII.—PERCHLORIDE OF PHOSPHORUS.

Experiments of MITSCHERLICH, CAHOURS, WURTZ, and TROOST and HAUTEFEUILLE.

Temperature.	Pressure.	Density calc. by eq. (18).	Density observed. Mitsch.	Density observed. Cahours.	Excess of observed density. Mitsch.	Excess of observed density. Cahours.
336	(760)	3·610		3·656		+·046
327	754	3·614		3·656		+·042
300	765	3·637		3·654		+·017
289	(760)	3·656		3·69		+·034
288	763	3·659		3·67		+·011
274	755	3·701		3·84		+·139
250	751	3·862		3·991		+·129
230	746	4·159		4·302		+·142
222	753	4·344	4·85		+·506	
208	(760)	4·752		4·73		—·021
200	758	5·018		4·851		—·167
190	758	5·368		4·987		—·381
182	757	5·646		5·078		—·568
			Wurtz.	T. & H.	Wurtz.	T. & H.
178·5	227·2	5·053		5·150		+·097
175·8	253·7	5·223		5·235		+·012
167·6	221·8	5·456		5·415		—·041
154·7	221	5·926		5·619		—·307
150·1	225	6·086		5·886		—·200
148·6	244	6·169		5·964		—·205
145	391	6·45	6·55		+·10	
145	311	6·37	6·70		+·33	
145	307	6·36	6·33		—·03	
144·7	247	6·287		6·14		—·147
137	281	6·53	6·48		—·05	
137	269	6·51	6·54		+·03	
137	243	6·48	6.46		—·02	
137	234	6·47	6·42		—·05	
137	148	6·31	6·47		+·16	
129	191	6·59	6·18		—·41	
129	170	6·56	6·63		+·07	
129	165	6·55	6·31		—·24	

* Pogg. Ann., vol. xxix (1833), p. 221.

† Comptes Rendus, vol. xxi (1845), p. 625; and Annales de Chimie et de Physique, Ser. 3, vol. xx (1847), p. 369.

‡ Comptes Rendus, vol. lxxvi (1873), p. 601. § Ibid., vol. lxxxiii (1876), p. 977.

pressure was reduced by mixing the vapor with air. In Table VIII all these determinations are compared with the formula

$$\log \frac{3\cdot6\,(D-3\cdot6)}{(7\cdot2-D)^2} = \frac{5441}{t_C+273} + \log p - 14\cdot353. \qquad (13)$$

The differences between the calculated and observed values are often large, in six cases exceeding ·30; but they exhibit in general that irregularity which is characteristic of errors of observation. We should expect large errors in the observed densities, on account of the difficulty of obtaining the substance in a state of purity, and because the large value of the density renders it very sensitive to the effect of impurities which diminish the density,—also because the specific heat of the vapor is great, as shown by the numerator of the fraction in the second member of (13),* and because the density varies very rapidly with the temperature as seen by the numbers in the third column of Table VIII.

But at the two lowest temperatures of Cahours' experiments, the differences of the observed and calculated densities (·381 and ·568) are not only great, but exhibit, in connection with the adjacent numbers, a regularity which suggests a very different law from that of the formula. In fact, the densities obtained by Cahours at atmospheric pressure and those obtained by Troost and Hautefeuille at pressures a little less than one-third of an atmosphere seem to form a continuous series, notwithstanding the abrupt change of pressure. Yet it is difficult to admit that the density is independent of the pressure. So radical a difference between the behavior of this substance and that of the others which we have been considering requires unequivocal evidence. Now it is worthy of notice that the experiment at 182°, in which the greatest discrepancy is seen, is not given in the first record of the experiments, which was in the Comptes Rendus in 1845. It is given in the Annales de Chimie et de Physique in 1847, where it is called the first experiment. (The experiment at 336° is also omitted in the Comptes Rendus and that at 208° in the Annales,—otherwise the lists are the same.) If it was the first experiment in point of time, which is apparently the meaning, it was made before the publication in the Comptes Rendus, and we can only account for its omission by supposing that it was a preliminary experiment, in which its distinguished author did not feel sufficient confidence to include it at first with his other determinations, although he afterwards concluded to insert it. If we reject this observation as doubtful, the disagreement between the formula and observation, appears to be within the limits of possible

* Compare Trans. Conn. Acad., vol. iii, p. 243, and pp. 286, 287 of this volume.

›r, but additional experiments will be necessary to confirm formula.*

͡xperiments have also been made by M. Wurtz in which vapor of the perchloride of phosphorus was diluted with t of the protochloride.† These experiments may be used ›est equation (8), which, when the values of its constants are ermined by equation (13), reduces to the form

$$\log \frac{p_1}{p_2 p_3} = \frac{5441}{t_C + 273} - 13{\cdot}751, \qquad (14)$$

ere p_1, p_2, and p_3 denote the partial pressures due respectively to the PCl_5, the Cl_2, and the PCl_3, existing as such in the ·mixture. Since these quantities cannot be the subjects of nediate observation, a farther transformation of the equation l be convenient. Let M_2, M_3 denote the quantities of the tochloride and of chlorine of which the mixture may be ned, and P_2, P_3 the pressure which would belong to each of se if existing by itself with the same volume and tempera-. These quantities will be connected by the equations

$$P_2 = \frac{kt\,M_2}{2{\cdot}22\,v}, \qquad P_3 = \frac{kt\,M_3}{4{\cdot}98\,v}, \qquad (15)$$

ere k denotes the same constant as on page 286. From the lent relations

$$P_2 = p_1 + p_2, \qquad P_3 = p_1 + p_3, \qquad p = p_1 + p_2 + p_3,$$

obtain

$$p_1 = P_2 + P_3 - p, \qquad p_2 = p - P_3, \qquad p_3 = p - P_2;$$

by substitution of these values in equation (14),

$$\log \frac{P_2 + P_3 - p}{(p - P_2)\,(p - P_3)} = \frac{5441}{t_c + 273} - 13{\cdot}751. \qquad (16)$$

view of the relations (15), this may be regarded as an equa- between the pressure, the temperature, the volume, and quantities of protochloride of phosphorus and chlorine into ch the gas-mixture is resolvable.

t is in this form that we shall apply the equation to the ›eriments of M. Wurtz, the results of which are exhibited in ›le IX. The first column gives the number distinguishing ı experiment in the original memoir; the second, the tem-ıture; the third the observed pressure (p) of the mixture

* Additional experiments on the density of this vapor have been made by M. ›urs, concerning which he says in 1866: "Les déterminations qui je viens ectuer à 170 et 172 degrés (ce corps bout vers 160 à 165 degrés) m'ont ıé des nombres qui, bien que notablement plus forts que ceux que j'ai obtenus rieurement à 182 et 185 degrés, sont encore bien éloignés de celui que corres- l à 4 volumes." Comptes Rendus, t. 63, p. 16. So far as the present writer been able to ascertain, these determinations have not been published. The ıula gives 6·025 for 170° and 5·973 for 172°, at atmospheric pressure. The ber corresponding to four volumes is 7·20.

† Comptes Rendus, vol. lxxvi (1873), p. 601.

of PCl_5, PCl_3, and Cl_2, which is the barometric pressure corrected for the small quantity of air remaining in the flask; the fourth, the pressure π due to the *possible perchloride*, found by subtracting the pressure due to the excess of protochloride (this pressure is calculated from the theoretical density of the protochloride) from the total pressure; the fifth, the density δ of the possible perchloride calculated from its pressure π with the temperature and volume. The numbers of these five

Table IX.—Perchloride and Protochloride of Phosphorus.

Experiments on the mixed vapors by Wurtz.

No. of exp.	t_c	p (obs.)	π	δ	P_2	P_1	p calc. by eq. (16).	Excess of obs. value of p.
XII	173·29	756·1	423	6·68	392·4	725·5	760·7	−4·6
X	165·4	748·4	413	6·80	390·1	725·5	747·9	+ ·5
VII	176·24	751·0	411	6·88	392·7	732·7	773·1	−22·1
VIII	169·35	724·1	394	7·16	391·8	721·9	750·5	−26·4
V	175·26	743·3	343	7·03	334·9	735·2	764·4	−21·1
II	164·9	758·5	338	7·38	346·4	766·9	782·9	−24·4
XI	175·75	760·0	318	7·00	309·2	751·2	776·8	−16·8
IV	175·26	756·3	271	7·06	265·7	751·0	770·9	−14·6
IX	160·47	753·5	214	7·44	221·1	760·6	766·8	−13·3
I	165·4	760·0	194	7·25	195·3	761·3	768·5	− 8·5
VI	170·34	751·2	174	8·30	200·6	777·8	787·6	−36·4
III	174·28	742·7	168	7·74	180·6	755·3	766·5	−23·8

columns are taken from the memoir cited, except that the correction of the barometric pressures has been applied by the present writer in accordance with the data furnished in that memoir. The two next columns contain the values of P_2 and P_1. These would naturally be calculated from M_2 and M_1 by equations (15). But since the values of M_2 and M_1 have not been given explicitly, those of P_2 and P_1 have been calculated from the recorded values of π and δ. Since the weight of the *possible perchloride* is $\frac{7 \cdot 2}{2 \cdot 22}M_2$, we have

$$\delta = \frac{7 \cdot 2\, M_2 k t}{2 \cdot 22\, v \pi} = \frac{7 \cdot 2}{\pi} P_2.$$

Moreover,

$$p - \pi = P_1 - P_2,$$

since both members of the equation express the pressure due to the excess of the protochloride. The values of P_2 and P_1 were obtained by these equations.

The eighth column of the table gives the values of p calculated from the preceding values of t_c, P_1, and P_2, by equation (16); and the last column, the difference of the observed and calculated values of p. The average difference is 18^{mm}, or a little more than two per cent, the observed pressure being

almost uniformly less than the calculated value. This deficiency of pressure is doubtless to be accounted for by a fact which MM. Troost and Hautefeuille have noticed in this connection. The protochloride of phosphorus deviates quite appreciably from the laws of Mariotte, Gay-Lussac, and Avogadro, the product of the volume and pressure of a given quantity of vapor at 180° and the pressure of one atmosphere being 1·548 per cent less than at the same temperature and the pressure of one-half an atmosphere.* Now we may assume as a general rule that when the product of volume and pressure of a gas is slightly less than the theoretical number (calculated by the laws of Mariotte, Gay-Lussac, and Avogadro) the difference for any same temperature is nearly proportional to the pressure.† It is therefore probable that between 160° and 180°, at pressures of about one atmosphere, the product of volume and pressure for protochloride of phosphorus is somewhat more than three per cent less than the theoretical number. The experiments of Wurtz, as exhibited in Table IX, show that the pressure, and therefore the product of volume and pressure, (we may evidently give the volume any constant value as unity,) in a mixture consisting principally of the protochloride is on the average a little more than two per cent less than is demanded by theory, the differences being greater when the proportion of the protochloride is greater. The deviation from the calculated values is therefore in the same direction and about such in quantity as we should expect.‡

M. Wurtz has remarked that the average value of δ (the density of the *possible perchloride*) is nearly identical with the theoretical density of the perchloride, and appears inclined to attribute the variations from this value to the errors of experiment. Yet it appears very distinctly in Table IX, in which the experiments are arranged according to the value of π (the pressure due to the *possible perchloride*), that δ increases as π diminishes. The experiments of MM. Troost and Hautefeuille show that the coincidence remarked by M. Wurtz is due to the fact that on the average in these experiments the deficiency of the density of the possible perchloride (compared with the

* Troost and Hautefeuille, Comptes Rendus, vol. lxxxiii (1876), p. 334.

† Andrews, "On the Gaseous State of Matter." Phil. Trans., vol. clxvi (1876), p. 447.

‡ The deviation of the protochloride of phosphorus from the laws of ideal gases shows the impossibility of any *very close* agreement between such equations as have been deduced in this paper and the results of experiment in the case of gas-mixtures in which this substance is one of the components. With respect to the question whether future experiments on the vapor of the perchloride (alone, or with an excess of chlorine or of the protochloride), will reduce the disagreement between the calculated and observed values to such magnitudes as occur in the case of the protochloride alone, it would be rash to attempt to anticipate the result of experiment.

theoretical value) is counterbalanced by the excess of density of the protochloride. When $\pi > 400$, the effect of the deficiency in the density of the possible perchloride distinctly preponderates; when $\pi < 250$, the effect of the excess of density in the protochloride distinctly preponderates. But the magnitude of the differences concerned is not such as to invalidate the general conclusion established by the experiments of M. Wurtz, that the dissociation of the perchloride may be prevented (at least approximately) by mixing it with a large quantity of the protochloride.

Table for facilitating calculation.—The numerical solution of equations (10), (11), (12) and (13) for given values of t and p may be facilitated by the use of a table. If we set

$$\Delta = \frac{D}{D_1}, \tag{17}$$

$$L = \log \frac{1000\, D_1 (D - D_1)}{(2D_1 - D)^2} = \log \frac{1000\,(\Delta - 1)}{(2 - \Delta)^2}, \tag{18}$$

we have for peroxide of nitrogen,

$$L = \frac{3118{\cdot}6}{t_C + 273} + \log p - 9{\cdot}451; \tag{19}$$

for formic acid,

$$L = \frac{3800}{t_C + 273} + \log p - 9{\cdot}641; \tag{20}$$

for acetic acid,

$$L = \frac{3520}{t_C + 273} + \log p - 8{\cdot}349; \tag{21}$$

and for perchloride of phosphorus,

$$L = \frac{5441}{t_C + 273} + \log p - 11{\cdot}353. \tag{22}$$

By these equations the values of L are easily calculated. The values of Δ may then be obtained by inspection (with interpolation when necessary) of the following table. From Δ the value of D may be obtained by multiplying by D_1, viz., by 1·589 for peroxide of nitrogen or formic acid, by 2·073 for acetic acid, and by 3·6 for perchloride of phosphorus.*

The constants of these equations are of course subject to correction by future experiments, which must also decide the more general question—in what cases, and within what limits,

* The value of Δ diminished by unity expresses the ratio of the number of the molecules of the more complex type to the whole number of molecules. Thus, if $\Delta = 1{\cdot}20$, in the case of peroxide of nitrogen there are 20 molecules of the type N_2O_4 to 80 of the type NO_2, or in the case of perchloride of phosphorus there are 20 molecules of the type PCl_5 to 40 of the type PCl_3 and 40 of the type Cl_2. A consideration of the varying values of Δ is therefore more instructive than that of the values of D, and it would in some respects be better to make the comparison of theory and experiment with respect to the values of Δ.

TABLE X.

For the solution of the equation: $\log \dfrac{1000\,(\Delta - 1)}{(2 - \Delta)^2} = L.$

L	Δ	Dif.	L	Δ	Dif.	L	Δ	Dif.
·7	1·005	1	3·0	1·382	39	5·3	1·932	7
·8	1·006	2	3·1	1·421	40	5·4	1·939	6
·9	1·008	2	3·2	1·461	39	5·5	1·945	6
1·0	1·010	2	3·3	1·500	37	5·6	1·951	5
1·1	1·012	3	3·4	1·537	37	5·7	1·956	5
1·2	1·015	4	3·5	1·574	35	5·8	1·961	4
1·3	1·019	5	3·6	1·609	33	5·9	1·965	4
1·4	1·024	6	3·7	1·642	31	6·0	1·969	3
1·5	1·030	7	3·8	1·673	30	6·1	1·972	3
1·6	1·037	9	3·9	1·703	27	6·2	1·975	3
1·7	1·046	10	4·0	1·730	26	6·3	1·978	2
1·8	1·056	13	4·1	1·756	23	6·4	1·980	2
1·9	1·069	15	4·2	1·778	22	6·5	1·982	2
2·0	1·084	18	4·3	1·800	19	6·6	1·[illegible]	2
2·1	1·102	20	4·4	1·819	18	6·7	1·986	1
2·2	1·122	24	4·5	1·837	17	6·8	1·987	2
2·3	1·146	26	4·6	1·854	14	6·9	1·989	1
2·4	1·172	30	4·7	1·868	14	7·0	1·990	
2·5	1·202	32	4·8	1·882	12	7·2	1·992	
2·6	1·234	34	4·9	1·894	11	7·4	1·994	
2·7	1·268	37	5·0	1·905	10	7·6	1·995	
2·8	1·306	[illegible]	5·1	1·916	9	7·8	1·996	
2·9	1·343	39	5·2	1·924	8	8·0	1·997	
3·0	1·382		5·3	1·932		9·0	1·999	

and with what degree of approximation, the actual relations can be expressed by equations of such form. In the case of perchloride of phosphorus especially, the formula proposed requires confirmation.

ART. XLIV.—*On a secular inequality in the Moon's Motion produced by the oblateness of the Earth;* by J. N. STOCKWELL.

HAVING been engaged, during a number of years past, in a thorough and systematic examination of the physical theory of the moon's motion, it seems proper to make known to astronomers, in advance of the publication of my researches which are now essentially completed, one of the most curious and interesting results at which I have arrived relative to the motion of our satellite.

It has been known, since the time of Newton, that the attraction of a spheroidal body on a point without its surface is different from that of a sphere having the same mass. If the spheroid be one of revolution, like the earth, the attraction depends not only on the distance of the attracted point from

the earth's center, but also on its distance from the equator. If the attracted point were situated in the plane of the earth's equator the attraction of the earth upon it would be greater at a given distance than if the earth were spherical. The attraction would also be greater either north or south of the equator until we reached the paralled of about 35° 16′, at which points the attraction of the earth would be nearly independent of its spheroidal form. For all points situated beyond the parallels of 35° 16′ the attraction of the earth is less than it would be if it were spherical.

From these general considerations we may draw the following conclusions: *First.* A body would revolve round the earth, at a given distance from its center, in less time if it moved in the plane of the equator, than it would if the earth were spherical; and its motion would be uniform. *Second.* The time of revolution would be increased if the body moved in a plane inclined to the equator, and its motion would not be uniform, on account of the redundancy or deficiency of matter beneath the different parts of its course. It is evident that the motion in an orbit perpendicular to the equator would suffer greater variations from the unequal distribution of matter, than it would for any other inclination.

We shall now apply the preceding considerations to the motion of the moon around the earth, supposing for greater simplicity that her orbit is circular.

Since the inclination of the moon's orbit to the equator is always less than 35° 16′, it follows that the earth's attraction on the moon is always greater than it would be if the earth were spherical. But since the inclination varies between the limits of about 18° 19′ and 28° 35′ during a period of about nineteen years, it follows that the earth's attraction undergoes sensible variations; and hence the moon's place at any given time requires to be corrected on account of the varying inclination of its orbit to the equator. The corrections to the moon's longitude and latitude arising from this cause have been calculated, and applied to the moon's place during the whole of the present century. All these varying inequalities in the forces would accurately compensate each other during each revolution of the moon's node, provided the mean inclination of the lunar orbit to the equator always retained the same value. Now the mean inclination of the moon's orbit to the equator is the same as the inclination of the ecliptic to the same plane; and since the inclination of the ecliptic to the equator is slowly becoming less, it follows that the plane of the moon's orbit is gradually approaching the plane of the equator; and hence its mean motion must be increasing. All these various conclusions are fully confirmed by mathematical analysis, and were first suggested by it.

Having thus shown the existence of a secular inequality in the moon's motion depending on the oblateness of the earth, it only remains to determine its amount. But as a mathematical analysis of the problem is not within the scope of the present paper, I shall be content with a mere statement of the semi-general formula together with its numerical value.

If we put ε_0 for the obliquity of the ecliptic in 1850, and ε for its value at any time t, and also suppose that the ellipticity of the earth is $\frac{1}{300}$, I find the following value for the secular inequality depending on the earth's oblateness, namely:

$$\delta v = +24''\cdot827 \int (\sin^2\varepsilon_0 - \sin^2\varepsilon)dt.$$

If we develop the integral into a series and retain only the first term we shall have

$$\int(\sin^2\varepsilon_0 - \sin^2\varepsilon)dt = +0\cdot008675\ i^2,$$

in which i denotes the number of centuries counting from 1850

Hence the secular inequality becomes

$$\delta v = 0''\cdot1981\ i^2.$$

This term, though small, is of sufficient importance to be used in computing ancient eclipses.

In conclusion I would state that I have found several inequalities in the moon's motion which are not recognized by existing theories, of even greater practical interest and importance than the one to which I have called attention in this paper.

Cleveland, Oct. 2, 1879.

ART. XLV.—*Discovery of two new Asteroids*; by Professor C. H. F. PETERS. Communication to the Editors dated Litchfield Observatory of Hamilton College, Clinton, N. Y., October 6, 1879.

TWO more planets of the asteroid group were found by me in the month of September, respectively on the 11th and 25th. I communicate the observations hitherto obtained.

(202) *Chryseïs.*

1879.	Ham. Coll. m. t.	App. Æ.	App. Decl.	No. of comp.
Sept. 11.	$12^h\ \pm^m$	$23^h\ 51^m\ 16^s$	$-\ 8°\ 53'\cdot5$	[rough estimate.]
Sept. 21.	13 18 27	23 44 15·93	− 9 58 4·4	10
Sept. 23.	12 7 56	23 42 53·47	−10 9 35·0	9
Sept. 26.	12 46 49	23 40 48·42	−10 26 55·2	10
Oct. 4.	8 56 13	23 35 39·12	−11 6 56·5	6

(203) *Pompeja.*

1879.	Ham. Coll. m. t.	App. Æ.	App. Decl.	No. of comp.
Sept. 25.	$14^h\ 48^m\ 21^s$	$0^h\ 57^m\ 6^s\cdot18$	$+\ 8°\ 15\ 30\cdot4$	12
Sept. 26.	13 41 15	0 56 19·53	+ 8 12 10·9	10
Oct. 4.	10 57 30	0 49 37·80	+ 7 41 41·8	14

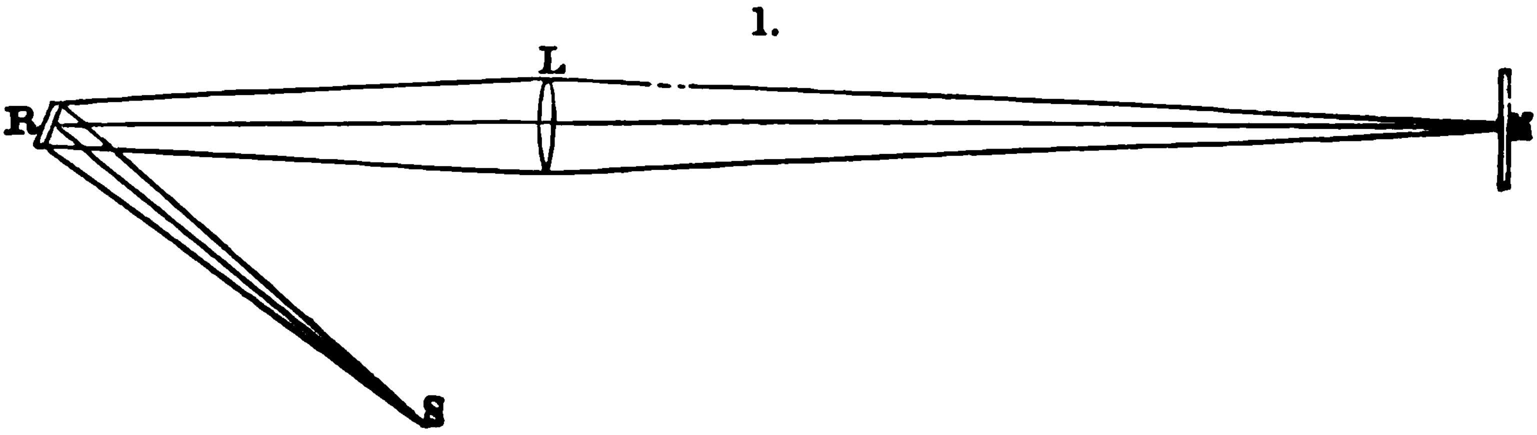
The magnitude of the first is now $11^m\cdot0$, that of the latter $10^m\cdot5$.

ART. XLVI. — *Experimental Determination of the Velocity of Light;* by ALBERT A. MICHELSON, Master, U. S. Navy.*

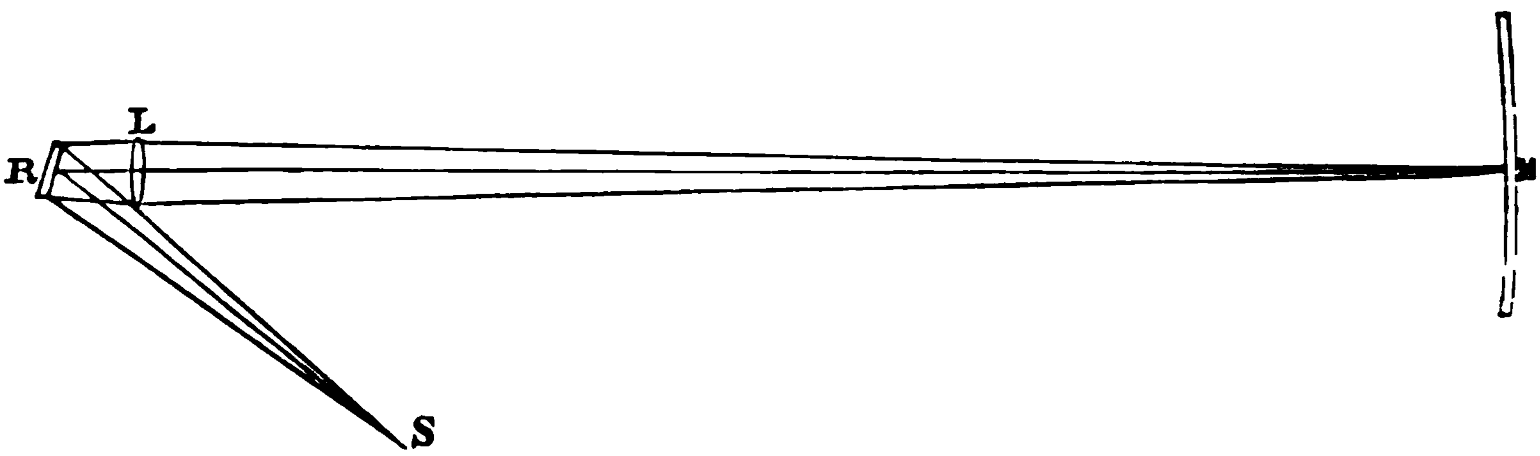
[Abstract of paper read before the American Association for the Advancement of Science.]

LET S, fig. 1, be a slit through which light passes, falling on R, a mirror free to rotate about an axis at right angles to the plane of the paper; L, a lens of great focal length, upon which the light falls, which is reflected from R. Let M be a plane mirror, whose surface is perpendicular to the line RM, passing through the centers of R, L and M, respectively. If L be so placed that an image of S is formed on the surface of M, then, this image acting as the object, its image will be formed at S, and will coincide point for point with S.

1.



2.



If, now, R be turned about the axis, so long as the light falls on the lens, an image of the slit will still be formed on the surface of the mirror, though on a different part, and as long as the returning light falls on the lens an image of this image will be formed at S, notwithstanding the change of position of the first image at M. This result, namely, the production of a stationary image of an image in motion, is absolutely essential. It was first accomplished by Foucault, and in a manner differing apparently but little from the foregoing.

In this case, L, fig. 2, served simply to form an image of S at M; and M, the returning mirror, was spherical, the center of curvature coinciding with the axis of R. The lens, L, was placed as near as possible to R. The light forming the return

* Prepared for this place by the Author.

image lasts, in this case, while the first image is sweeping over the face of the mirror, M. Hence, the greater the distance, RM, the larger must be the mirror, in order that the same quantity of light may be preserved, and its dimensions would soon become inordinate. The difficulty was partly met by Foucault, by using five concave reflectors instead of one; but even then the greatest distance he found it practicable to use was only twenty meters.

Returning to fig. 1, suppose that R is in the principal focus of the lens, L; then, if the plane mirror, M, have the same diameter as the lens, the first or moving image will remain upon M as long as the axis of the pencil of light remains on the lens, and *this will be true no matter what the distance may be.*

When the rotation of the mirror R becomes sufficiently rapid, then the flashes of light which produce the second or stationary image become blended, so that the image appears to be continuous. But now it no longer coincides with the slit, but is deflected in the direction of the rotation, and through twice the angular distance described by the mirror, during the time required for light to travel twice the distance between the mirrors. This displacement is measured by its arc, or rather, by its tangent. To make this as large as possible, the distance between the mirrors, the radius or distance from the revolving mirror to the slit, and the speed of rotation should be made as great as possible.

The second condition conflicts with the first, for the "radius" is the difference between the distances of the principal focus, and the conjugate focus (for the distant mirror). The greater the "distance," therefore, the smaller will be the "radius." There are two ways of solving the difficulty: first, by using a lens of great focal length, and, secondly, by placing the revolving mirror within the principal focus of the lens. Both means were employed. The focal length of the lens was 150 feet, and the mirror was placed fifteen feet within the principal focus. A limit is soon reached, however, for the quantity of light received diminishes very rapidly as the revolving mirror approaches the lens.

The chief objection urged in reference to the experiments made by Foucault is that the deflection was too small to be measured with the required degree of accuracy. This deflection was but a fraction of a millimeter, and when it is added that the image is always more or less indistinct on account of atmospheric disturbances, as well as imperfections of lenses and mirrors, it may well be questioned whether the results could be relied upon within less than one per cent.

In the following experiments the distance between the mirrors was nearly 2000 feet. The radius was about thirty

feet, and the speed of the mirror was about 257 revolutions per second. The deflection exceeded 133 millimeters, being about 200 times as great as that obtained by Foucault. If it were necessary it could be still further increased. This deflection was measured within three or four hundredths of a millimeter in each observation; and it is safe to say that the result, so far as it is affected by this measurement, is correct to within one ten-thousandth part.

The revolving mirror was actuated by a current of air which escaped through a turbine wheel on the same axle as the mirror. The supply of air was furnished by a blower, turned by a steam engine, the pressure being kept constant by a water-gauge attended by an assistant at the valve. To regulate and measure the speed of rotation a tuning-fork, bearing on one prong a steel mirror, was employed. This was kept in vibration by a current of electricity. The fork was so placed that the light from the revolving mirror was reflected to a piece of plane glass in front of the eye-piece, and thence reflected to the eye. When fork and mirror are both at rest, an image of the revolving mirror is perceived. When the fork vibrates, this image is drawn out into a band of light. When the mirror commences to revolve, this band breaks up into a number of moving images of the mirror; and when, finally the mirror makes as many turns as the fork makes vibrations, or any multiple, submultiple or simple ratio of this number, the images become stationary.

Hence, to make the mirror revolve at a given uniform speed, the cord attached to the valve, which leads to the observer's table, is pulled right or left, till the images of the revolving mirror come to rest.

The electric fork made about 128 vibrations per second. No dependence was placed upon this rate, however, but at each set of observations it was compared with a standard Ut_3 fork, the temperature being noted at the time.

The rate of the Ut_3 fork was found to be 256·072 at 65° F. The result obtained by Prof. Mayer and myself, at the Stevens Institute, was 256·068.

The apparatus for measuring the deflection consists of an accurate screw with divided circle. To the frame is attached an adjustable slit. On the screw travels a carriage which supports the eye-piece, which consists of an achromatic lens, having in its focus a single vertical silk fiber. The slit which is very nearly in the same focal plane as the silk fiber, is bisected by the latter, and reading of scale and circle taken. Then the screw is turned till the silk fiber bisects the deflected image of the slit, and reading taken again. The difference between the two readings gives the deflection.

The direction of rotation was right-handed. To eliminate any possible error which might arise on this account, the mirror in eight of the later observations was inverted, thus making the rotation left-handed, and the deflection was measured in the opposite direction. The results agreed well with those previously obtained with the mirror erect.

To eliminate errors due to a regular variation in speed during every revolution, if any such could exist, the position of the frame was changed in several experiments. The results were the same as before.

To test the question as to whether or not the vortex of air about the mirror had any effect on the deflection, the speed was lowered to 192, 128, 96, and 64 turns per second. If the vortex had any effect, it should have decreased with the lower speed, but no such effect could be detected. This also proves that any error due to distortion of the mirror must be excessively small, otherwise it also would have been diminished with the smaller speed, thus giving different results.

Finally, to test if there were any bias in making the observations, the readings in several sets were taken by another, and written down, without divulging them. The separate readings were as consistent as when made by myself, and the results still agreed with those of the other observations.

Results of Observations.

Every number is the mean of ten separate observations.

299710	299820	299740	299790	299790
299600	299800	299740	299710	299740
299760	299820	299740	299710	299680
299880	299800	299720	299720	299710
299740	299740	299580	299700	299660
299710	299660	299580	299670	299710
299810	299710	299480	299660	299690
299840	299740	299720	299640	299710
299840	299760	299830	299650	299770
299740	299700	299810	299660	299800
299860	299690	299740	299810	299820
299840	299650	299770	299820	299820
299790	299670	299710	299790	299710
299510	299740	299730	299760	299640
299620	299740	299740	299780	299810
299670	299690	299740	299620	299840
299860	299660	299750	299740	299780
299860	299650	299710	299750	299580
299820	299620	299740	299750	299560
299820	299660	299740	299680	299610

Mean result	299728
Cor. for temp.	+12 (of steel tape, scale and screw).
Vel. of light in air	299740
Cor. for vacuo	+80

Vel. of light in vacuo 299820 kilometers per second.

ART. XLVII.—*The Kane Geyser Well;* by CHARLES A. ASHBURNER, Assistant Second Geological Survey of Penn.*

THE Kane Geyser or Spouting Water-well, which during the past year has attracted such general attention from the "sight-seeing" public, is no novelty to the oil man. The cause of the action has been so erroneously represented, that a correct explanation seems to be demanded.

This well is situated in the valley of Wilson's Run, near the line of the Philadelphia and Erie Railroad, four miles southeast from Kane. It was drilled by Messrs. Gruhout and Taylor in the spring of 1878 to a total depth of 2,000 feet. No petroleum was found in paying quantities and the casing was drawn and the hole abandoned, since which time it has been throwing periodically—every ten to fifteen minutes—a column of water and gas to heights varying from 100 to 150 feet.

During the operation of drilling, fresh "water veins" were encountered down to a depth of 364 feet, which was the limit of the casing. At a depth of 1415 feet a very heavy "gas vein" was struck. This gas was permitted a free escape during the time the drilling was continued to 2,000 feet.

When the well was abandoned, from failure to find oil, and the casing drawn, the fresh water flowed into the well and the conflict between the water and gas commenced, rendering the well an object of great interest. The water flows into the well

* The above notice of this remarkable water-and-gas geyser is from Stowell's Petroleum Reporter (Pittsburgh, Pa.) for Sept. 15th. The view of the Geyser is copied from a photograph sent to the editors by Mr. Ashburner. A fuller description of a similar and adjoining well by Mr. Ashburner appeared in 1877 in the Transactions of the American Philosophical Society, and is noticed in this Journal in volume xvi, at page 140, 1878.

on top of the gas, until the pressure of the confined gas becomes greater than the weight of the superincumbent water, when an expulsion takes place and a column of water and gas is thrown to a great height. This occurs at present at regular intervals of thirteen minutes and the spouting continues for one and a half minutes. On July 31, Mr. Sheafer (aid, McKean County) measured two columns, which went to heights respectively of 120 and 128 feet. On the evening of August 2d, I measured four columns in succession and the water was thrown to the following heights: 108, 132, 120 and 138 feet. The columns are composed of mingled water and gas, the latter being readily ignited. After night-fall the spectacle is grand. The antagonistic elements of fire and water are so promiscuously blended, that each seems to be fighting for the mastery. At one moment the flame is almost entirely extinguished, only to burst forth at the next instant with increased energy and greater brilliancy. During sunshine the sprays form an artificial rainbow, and in winter the columns became incased in huge transparent ice chimneys.

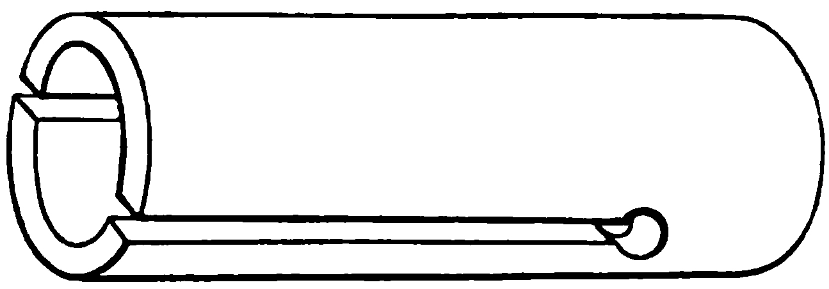
A number of wells in the oil regions have thrown water geysers similar to the Kane well, but none have ever attracted such attention.

As early as 1833 a salt well, drilled in the valley of the Ohio, threw columns of water and gas, at intervals of ten to twelve hours, to heights varying from fifty to one hundred feet. This well is possibly the first of the "water and gas geyser wells."

ART. XLVIII.—*On a Resonant Tuning Fork;* by THOMAS A. EDISON, Ph.D., Menlo Park, N. J.

[Read at the Saratoga meeting of the American Association.]

FOR the purpose of rendering audible the sounds produced by tuning forks, they are generally mounted upon resonant boxes containing a column of air whose vibrating period is the same as that of the fork. I have devised a modification of this



plan, by which the box is dispensed with, the resonant chamber, as is shown in the cut, being formed by the prongs themselves. To make the fork, a thick tube of bell-metal, one end of which is closed, has a slit sawed longitudinally through its

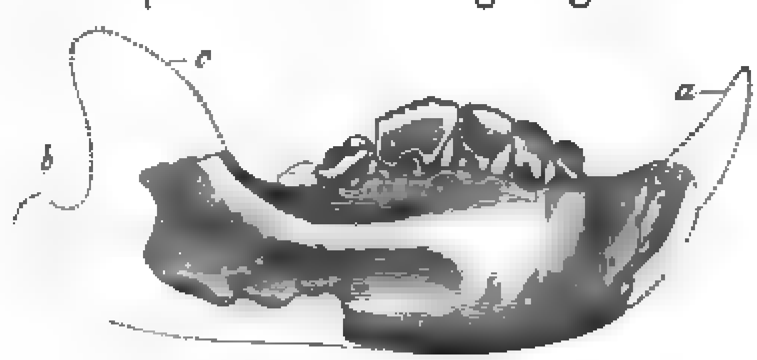
center, the slit being nearly to the closed end. This slit divides the tube equally and gives two vibrating prongs, analogous to those of a fork. To bring the prongs into unison with the column of air between them, the tube is put in a lathe and turned thinner until the desired point is reached and the two are in unison. Thereupon the sound of the fork is powerfully reinforced.

ART. XLIX.—*Notice of New Jurassic Mammals;* by Prof. O. C. MARSH.

ADDITIONAL remains of mammals from the Jurassic of the Rocky Mountains indicate that this class constituted an important element in the Mesozoic fauna of this country. The forms already described,* as well as those noticed below, show moreover, such a resemblance to known types from the Purbeck of England, that some connection between the two faunæ is clearly implied, and future discoveries will be awaited with interest.

Ctenacodon serratus, gen. et sp. nov.

One of the most interesting specimens yet brought to light is a diminutive right lower jaw, with most of the teeth in excellent preservation. This specimen differs widely from the remains hitherto found in this country, but agrees in its main features with the genus *Plagiaulax* of Falconer.† From the type species of that genus (*P. Beckelsii*), it differs in having four lower premolars instead of three; while from all the described species, it may be distinguished by the absence of the characteristic oblique grooves on the sides of the premolar crowns. This specimen is represented in the figure given below.



Right lower jaw of *Ctenacodon serratus*, Marsh; about four times natural size. *a.* incisor; *b.* condyle; *c.* coronoid process.

This lower jaw is short and massive. Its outer surface is marked by a strong ridge, which begins below the first premolar, and is continued to the base of the coronoid process.

* This Journal, vol. xv, p. 459, 1878; vol. xviii, pp. 60 and 215, 1879.
† Journal Geological Society of London, vol. xiii, p. 261. 1857.

The symphysis is short, and the two rami were not firmly coössified. The lower dental series is as follows:

Incisors 1–1; premolars 4–4; molars 2–2.

The incisor was large, and had a compressed base. The premolars are wedge-shaped, and all have sharp trenchant crowns. The summit of each is very thin, and the last is distinctly serrated. The first lower molar had a low crown, very similar to that of *Plagiaulax*.

The following are the principal dimensions of this specimen:

Length of portion preserved	11· mm
Space occupied by lower teeth	8·5
Space occupied by four premolars	4·5
Depth of jaw below first premolar	2·5
Depth of jaw below last premolar	3·5
Height of crown of last premolar	1·5

A second specimen, also a right lower jaw, agrees essentially with the one here described. Both are from the same locality, in the Atlantosaurus beds of Wyoming. These fossils, with those of the genus *Plagiaulax*, belong to a well marked family, which may appropriately be termed *Plagiaulacidæ*.

Dryolestes arcuatus, sp. nov.

A third species of *Dryolestes* is at present represented by five specimens, two upper, and three lower jaws. This species may be distinguished from those already described by the upper and lower molar teeth, which are small, crowded together, and placed on a curve, the former with the convexity outward. The specimen which may be regarded as the type of this species is an upper jaw, with six molar teeth in place. Between these and the canine, there were at least four premolars. The teeth of the lower jaw were small, and numerous, and in one specimen appear to have been arranged on a curve opposite to that of the upper molars.

The principal measurements of the type specimen are as follows:

Space occupied by teeth in maxillary	15· mm
Space occupied by six posterior molars	7·
Height of maxillary above second premolar	5·
Space occupied by first three upper molars	3·5

The known remains of this species indicate an animal about as large as a weasel. The species now described represent a distinct family, which may be called *Dryolestidæ*.

Tinodon robustus, sp. nov.

A species of this genus, about twice as large as the one previously described (*T. bellus*), is indicated by a lower jaw with

several teeth in good preservation. The lower molars have a strong basal ridge on the inner surface of their crowns. The ramus of the lower jaw is compressed. The mylo-hyoid groove is well marked, and is continued forward much further than in the smaller species.

The main dimensions of this specimen are as follows:

Space occupied by four lower molars	9·mm
Depth of jaw below first lower molar	4·
Depth of jaw below last lower molar	5·
Height of penultimate molar above inner side of jaw	2·

This specimen pertained to an animal about the size of the preceding species.

Tinodon lepidus, sp. nov.

Another species of *Tinodon*, the smallest yet found, is represented by a left lower jaw, in fair preservation. This specimen differs from the type of *T. bellus*, which it most resembles in size, in having smaller teeth, the inner margin of the jaw somewhat inflected, and the angle extending downward below the condyle, instead of being emarginate at this point. The condyle, moreover, is on a level with the base of the teeth, and not above their crowns, as in the type species.

The present specimen measures as follows:

Distance from first molar to end of condyle	15·mm
Space occupied by four molar teeth	6·
Depth of jaw below first lower molar	2·5
Depth of jaw below condyle	2·

All the specimens here described are from the same locality, in the Upper Jurassic of Wyoming, and are now preserved in the Yale Museum.

Yale College, New Haven, October 22d, 1879.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On a new method of preparing Hyponitrous acid.*—Since the method of preparing sodium hyponitrite by reducing sodium nitrite with sodium amalgam is long and tedious and the yield small, Zorn has devised an electrolytic method for producing it, which works well. At first he used platinum electrodes in a concentrated solution of sodium nitrite; but with no result. He then made the negative electrode of mercury, using four Bunsen cells. A pretty active evolution of gas begins in a short time, the gas, however, containing no ammonia. If the current be broken after a short time, the liquid neutralized with acetic acid, and treated

with silver nitrate, an abundant precipitate of silver hyponitrite, AgNO, is thrown down. If the electrolysis be continued too long, i. e., after the evolution of ammonia begins, the silver hyponitrite falls as before on adding silver nitrate to the neutralized liquid, but is immediately decomposed with evolution of gas and deposition of metallic silver. This reaction shows, therefore, the production of hydroxylamine in this electrolysis. The yield of hyponitrite is good and the author recommends this process as much preferable to that by sodium.—*Ber. Berl. Chem. Ges.*, xii, 1509, Sept., 1879. G. F. B.

2. *On the Direct Union of Calcium oxide and Carbon dioxide.*—It is well known that at a high temperature, calcium oxide unites directly with carbon dioxide, while they have no action at ordinary temperatures. BIRNBAUM and MAHN have sought to determine more exactly the temperature at which this action commences. Pure lime was prepared by igniting marble in a platinum crucible, slaking it with water repeatedly and igniting until the weight was constant. Pure dry carbon dioxide was passed over weighed portions of this lime, contained first in a boat in a porcelain tube, and afterward in a bulb of Bohemian glass, the heat being that of a paraffin bath heated from 160° to 320° C. The weight remained unchanged. Experiments made with baths of lead and tin alloys fusing at from 230° to 290°, or of pure lead fusing at 236·2°, gave the same result. The first absorption was observed when the bulb was placed in melted zinc, 415·3°. After five to eight hours, 100 parts of lime absorbed 4·1 per cent CO_2, after thirteen hours 15·2 per cent, after forty hours 31·6 per cent, and after fifty hours 45·7 per cent. Since 100 parts of lime requires 78·57 parts CO_2, but a little more than half the quantity required to form $CaCO_3$ was taken up in this time. On heating for sixty hours, only 21·1 per cent was absorbed. Hence dissociation must also take place at this temperature. To test the question, precipitated calcium carbonate was treated in a slow current of dry air in the zinc bath. After ten hours 0·78 grams had lost 0·011 grams; but farther heating did not increase this quantity. The temperature of union and of dissociation of calcium carbonate is therefore about 400°.—*Ber. Berl. Chem. Ges.*, xii, 1547, Sept., 1879. G. F. B.

3. *On the new Element, Scandium.*—CLÈVE has studied the new earth scandia, discovered by him, a few weeks after Nilson's announcement of it, in gadolinite and yttrotitanite, the former containing 0·002 to 0·003 and the latter 0·005 per cent of scandium. Scandia has the formula Sc_2O_3, ammonio- and potassio-scandium sulphates, and also the oxalates and selenites, establishing it. From eight to ten grams of scandia, by repeated decompositions of the nitrate, one gram of a white earth was obtained. This was converted into sulphate and calcined; 1·451 grams gave 0·5293 of scandia, which gives for the atomic weight of scandium 44·01. If scandia be taken as ScO, the above result gives as its molecular weight 45·94; differing essentially from 105·83 the minimum

value given by Nilson. Careful examination by Thalén with the spectroscope, proved Clève's scandia to be pure; hence he infers that in the 0·3298 gram of scandia on which Nilson worked there must have been only 0·043 of scandia and seven or eight times as much ytterbia. Clève concludes on 45 as the atomic weight of scandium. Scandia Sc_2O_3 is a perfectly white light powder, infusible and resembling magnesia. Acids, even the strongest, attack it with difficulty; still, it is more soluble than alumina. Its density is about 3·8. The hydrate is white and bulky like that of alumina. It does not attract CO_2 from the air, is insoluble in excess of ammonium or potassium hydrates, and does not decompose salts of ammonium. Its salts are colorless, with an acid and astringent taste, quite different from the sweet taste of the other yttria-earth salts. The sulphate does not give distinct crystals; but the nitrate, oxalate, acetate, and formate are crystallizable. The chloride gives no spectrum when heated in a gas flame. Its solution is precipitated by ammonium and potassium hydrates, the precipitate being insoluble in excess. Tartaric acid prevents the precipitation by ammonia in the cold. Sodium carbonate gives a precipitate soluble in excess. H_2S gives no precipitate, $(NH_4)HS$ throws down the hydrate, sodium phosphate gives a gelatinous precipitate. Oxalic acid gives a curdy precipitate which becomes rapidly crystalline. Sodium hyposulphite and sodium acetate precipitate readily boiling solutions, though incompletely. What renders the discovery of scandium particularly interesting is the fact that its existence and properties were predicted by Mendelejeff, as a consequence of his law of periodicity, and called *ekabor*. The remarkably close correspondence of the properties of ekabor with those of scandium is shown by printing them in parallel columns in Clève's memoir.—*C. R.*, lxxxix, 419, Aug., 1879.

G. F. B.

4. *On two new Elements, Thulium and Holmium.*—Since the ytterbium of Marignac and the scandium of Nilson, both of which were discovered in erbia, give colorless salts, CLÈVE has sought to distinguish the substance in this earth which gives the red color and the beautiful absorption spectrum to its salts, in order to ascertain if it was erbium itself. Using the residues from which Nilson had separated the ytterbia and the scandia, he found it impossible to obtain a red oxide with a constant molecular weight, even after several hundred decompositions. Suspecting the presence of an unknown oxide, he applied to Thalèn to examine the spectrum of what he regarded as the purest erbia, and to compare it with that of yttria and of ytterbia. Certain absorption bands in the last fractions suggested that the color of erbia is due to the presence of three oxides giving absorption spectra. The reddest of the fractions (RO mol. wt., 126–127) were united and submitted to a long series of decompositions, one fraction being treated for ytterbia, another for yttria, and a third, intermediate, containing the concentrated erbia. At the same time, he attempted to concentrate the coloring matter in residues A, rich

in ytterbia, and B in yttria. After pushing the treatment as far as possible with the amount of material in hand, he submitted the five fractions to Thalèn, who found bands common to all the fractions and hence due probably to erbia. These had the following wave-lengths: 6660–6680 (weak), 6515–6545 (strong), 6475–6515 (quite strong), 5400–5415 (quite strong), 5225–5235 (very strong), 5185–5225 (strong), 4865–4877 (strong), 4475–4515 (quite strong). The following bands varied markedly from one fraction to another:

	Wave-length.	*Fraction A.* Extr. from ytterbia residues.	Extr. from erbia 126-7.	*Erbium?* Mean fractions 126-7.	*Fraction B.* Extr. from erbia 126-7.	Extr. from residues rich in yttrium.
x	6480	strong	quite strong	fails	fails	fails
y	6400–6425	fails or trace	trace	weak	weak	pretty strong
z	5360	fails	fails or trace	trace	feeble	quite strong

Hence *x* belongs to fractions situated near ytterbia and does not exist in fractions from yttrium. But, on the other hand, *y* and *z* fail in the ytterbium residues but grow sharper as yttrium is approached. The ytterbia fractions gave a rose color, with a tinge of violet; the yttria fractions had an orange tint. For the element between ytterbia and erbia, characterized by band *x* in the red of the spectrum, Clève proposes the name *Thulium*, from Thule, the ancient name of Scandinavia. The atomic weight, Tm, should be about 113 if its oxide is RO. Erbium proper, which has the common bands mentioned, has the atomic weight 110–111. Its oxide is of a clear rose color. The third metal present, characterized by the *y* and *z* bands, and which is between erbia and terbia, should have an atomic weight below 108. Its oxide appears to be yellow. For it, the name *Holmium* is proposed, derived from the Latin name of Stockholm, the environs of which are rich in yttria minerals.—*C. R.*, lxxxix, 478, Sept., 1879.

G. F. B.

5. *Notes on the two new Elements announced by Clève.*—Soret has called attention to the fact that he pointed out in the spring of 1878, the two bands which characterize holmium, as not belonging to erbia, but to a new earth which he called provisionally X and which is perhaps identical with philippium since discovered by Delafontaine. Beside these two bands, Soret recognized three other absorption bands; one less refrangible than A, a second overlapping the band of erbia in the indigo, and a third, faint, in the violet a little beyond *h*. In the ultra violet-spectrum six absorption-maxima exist from H to R. In samarskite, the earth X is, relatively to erbia much more abundant than in gadolinite. As to the red ray which characterizes thulium, Soret had already observed that also in some ytterbia products which had been sent to him for examination by Marignac. Lecoq de Boisbaudran confirms Soret's statement in regard to the red thulium ray, hav-

ing observed it in a sample of impure ytterbia which he had received from the latter some months ago. He inclined to the belief that all the bands were due to erbia, modified by the conditions. But special experiments led him to coincide in Soret's views and to conclude in the possibility that erbia was a mixture of three oxides.—*C. R.*, lxxxix, Sept., 1879. G. F. B.

6. *An Introduction to the Practice of Commercial Organic Analysis;* being a Treatise on the properties, proximate analytical examination, and modes of assaying the various organic chemicals and preparations employed in the Arts, Manufactures, Medicine, etc. With concise methods for the Detection and Determination of their Impurities, Adulterations and Products of decomposition; by Alfred H. Allen, F.C.S., Lecturer on Chemistry at the Sheffield School of Medicine, etc. Volume I. Philadelphia, 1879. (Lindsay & Blackiston.)—In preparing this book, Mr. Allen has done a good service for the public analyst. The great activity in organic research in recent years has resulted in the production of a large number of compounds whose valuable properties have led to their commercial utilization. Except, however, in the original memoirs where they were described, the properties and reactions of many of these compounds have remained comparatively unknown, and hence their adulteration has been an easy matter. In gathering together the physical and chemical properties of these substances into a convenient volume, and especially in doing this with the care and scientific accuracy which Mr. Allen has evidently exercised, a valuable aid has been rendered in protecting the public from imposition. The volume before us is the first of two which the author has projected. After a brief introduction, in which are given the methods of the preliminary examination of organic bodies, the study of their physical properties, their solubility in various menstrua, their ultimate or elementary analysis, and the production of definite compounds from, and the products of decomposition of, organic bodies, the author takes up several classes of these organic bodies in the following order: Cyanogen and its derivatives, alcohols, neutral alcoholic derivatives, acid alcoholic derivatives and vegetable acids, phenols, and the acid derivatives of phenols. The individual members of each class which are of commercial importance are, in general, quite fully considered, their origin, mode of preparation, physical and chemical properties, reactions, and adulterations, being discussed in order. This portion of the work appears to be entirely reliable, and leads us to hope that the second volume may soon be forthcoming. In reproducing it here, the American publishers have strengthened the cause of sanitary chemistry in this country. G. F. B.

7. *Laboratory Teaching:* or Progressive Exercises in Practical Chemistry; by Charles London Bloxam, Professor of Chemistry in King's College, London, etc. Fourth Edition, with eighty-nine illustrations. Philadelphia, 1879. (Lindsay & Blakiston.)—Chemical text-books may be divided into two classes,

those which teach Chemistry as a science and aim to make chemists, and those which teach it as an art and aim to make analysts. Professor Bloxam's book, to judge from the somewhat extraordinary preface to the fourth edition, belongs evidently to the latter class. He says: "The most important alteration in the present edition is the introduction of the formulæ representing the various chemical compounds described in the notes to the tables. The formulæ are those now generally employed by chemical writers and teachers in this country. The verbal description of the composition, in the Tables of Common Compounds of the several metals, has not been altered so as to bring it into perfect harmony with the formulæ, since the description there given generally informs the learner what substances can be obtained by the decomposition of the Common Compounds which is not so easily to be ascertained by an inspection of the formulæ. For example, the composition of saltpeter is described at page 81 as Potash (Potassium and Oxygen) and Nitric Acid, while the formula KNO_3 does not indicate the presence of potash (K_2O) or of nitric acid (HNO_3); but both these substances are obtainable from saltpeter by very simple chemical operations, and saltpeter may be produced by causing them to act upon each other. It is true that similar reasoning would justify the statement that common salt contained soda and hydrochloric acid instead of sodium and chlorine, but the author feels that an endeavor to be absolutely consistent would injure the practical usefulness of so small a book." Hence we are not surprised to find that Na_2SO_4 is called sulphate of soda and that it is said to be composed of soda and sulphuric acid; or to be told that sulphate of ammonia $(NH_4)_2SO_4$, is composed of ammonia, water, and sulphuric acid. In the first edition, it is claimed as a merit that the book "does not enter into any theoretical speculations." In the light of the preface to the fourth edition and of the instances just quoted, we have to differ from that opinion, reminding the author that unexploded theories are less dangerous to teach, than exploded ones. Viewed from the author's stand-point, however, the book has some good points. The methods of manipulation are well described and illustrated, the leading reactions of the more commonly occurring substances are clearly given, and the processes for the qualitative determination of unknown mixtures are plainly tabulated. The mechanical execution of the book is excellent. G. F. B.

8. *Solar Physics.*—On the occasion of the partial eclipse observed at Marseilles on the 19th of July, 1879, M. JANSSEN applied the photographic method of observing contacts. The observation of partial eclipses have long been considered inaccurate for the determination of position; the difficulties of taking precise micrometric measurements upon the sun and the determination of the instant of contact are well known. M. Janssen proposes to take, by means of a *revolver*, a number of solar images of $0^m{\cdot}06$ to $0^m{\cdot}10$ in diameter, at intervals of one second. By optical methods the contacts cannot be observed with precision, on

account of the small deformation of the solar disc, when the moon encroaches upon it. With the *revolver* one can obtain a series of negatives which include the critical moment of contact. These negatives can be examined at leisure. These photographs also can be used to determine the relative position of the two heavenly bodies at the different intervals of time, and by this means check the above method of observing contacts. The method is also of use in studying the character of the sun's surface. If the moon's disc is absolutely free from a gaseous envelope, the solar granulation preserves its forms and its character up to the edge of the occulting moon. If, however, a gaseous envelope of considerable size interposes itself, it will act under the most favorable conditions for producing these deformations by refraction. The existence and the value of these deformations of the granulations at the edge of the occulting moon will therefore become a very sure test of the presence and density of this atmosphere. This method also allows of the determination of the height of the lunar mountains situated on the edge of the moon's limb, in a position where the methods of measurement hitherto used have been the most difficult and the most inexact. The photographs of the edge of the sun upon which the moon's limb encroaches gives the contour of all the inequalities of the surface of the moon which are projected upon the sun. By micrometric measurements and comparison with the sun's disc, one can readily obtain the relative size of these inequalities of surface. These measurements together with those of the angles they subtend, as seen from the earth, afford the means of obtaining their true size. This method of observation was employed on the occasion of the late eclipse at Marseilles. Some solar photographs $0^{m}\cdot30$ in diameter were taken. These photographs show the granulations; but do not give any evidence of a change on the moon's limb. They however show very clearly the inequalities of the lunar contour, and allow of micrometric measurements of the heights of these inequalities.—*Comptes Rendus*, No. 6, 1879, p. 340. J. T.

9. *Density of the light Ether.*—Herr P. GLAN criticizes the conclusions of Sir William Thomson that the mass M of a cubic foot of ether is greater than $\frac{83g}{V^2n^2}$ pounds, where g is the gravitation constant, V the velocity of light, and n the ratio of the greatest velocity of a rotating ether particle to the velocity of light. The value of n taken by Thomson is $\frac{1}{50}$ and the resulting value of M is greater than $\frac{1}{1560 \cdot 10^{17}}$ pound. According to Thomson it lies in the nature of wave-movement that the ratio of the greatest velocity of a swinging particle to the velocity of light must be small, and if the ratio $\frac{1}{50}$ is taken the resulting value of M must be below the true value. Herr Glan, from theoretical conclusions upon the limit of actual disruption of the ether, doubts the conclusions of Thomson. The passage of the heavenly bodies through the ether of space must tend to separate the ether particles, and since the ether offers no sensible opposition to the pas-

sage of these bodies, it is concluded that very little energy is needed to effect any separation of ether particles which may take place, and the greatest possible dilatation of this ether must be much smaller than is the case with glass or water. In comparing authorities, Herr Glan finds that taking the greatest possible dilatation of glass before disruption at $\frac{1}{1443}$ the value of $n=\frac{1}{27}$ which is twice the value taken by Thomson. For the greatest possible dilatation of water under the same conditions, the value of $\frac{1}{37 \cdot 106}$ is taken. This gives the value $n=\frac{1}{4306}$ if the dilatation of the ether before disruption is as great as in the case of water. This value of n shows that the ether in a definite space possesses more mass than the hundred billionth part of this space, if it were filled with hydrogen at its normal density. The lower limit of the density of ether, according to this calculation, would therefore be 7416 times greater than that given by Thomson.—*Annalen der Physik und Chemie*, No. 8, 1879, p. 640. J. T.

10. *Mechanical Equivalent of Heat.*—H. Carnot has presented to the French Academy a series of his brother Sadi's manuscripts written between 1824 and 1832. From these papers it appears that Sadi Carnot had discovered the mechanical equivalence of heat and work. The following is an extract from these papers: "Heat is then the result of a movement. It can be produced by the consumption of motive power, and it can produce this power. When there is destruction of motive power, there is at the same time a production of heat exactly equivalent to the motive power destroyed. Reciprocally when there is destruction of heat there is production of motive power. According to some ideas which I have formed upon the theory of heat, the production of a unit of motive power necessitates the destruction of 2·70 units of heat." The unit of work taken is that which will lift one cubic centimeter of water one meter high. This unit is 1000 kilogrammeters. The mechanical equivalent of heat, according to this, would be $\frac{1000}{2 \cdot 71}$ $=370$ kilogrammeters. The first determination of Mayer in 1842 gave 365 kilogrammeters. Joule's result is 425. The publication of this result of Carnot was prevented by his death, which occurred at the early age of 36.—*Beiblatter*, *Annalen der Physik und Chemie*, No. 8, 1879, p. 584. J. T.

11. *Units and Physical Constants;* by Professor J. D. Everett. 175 pp., small 8vo. London, 1879. (Macmillan & Co.).—The author of this work was the Secretary of the Committee of the British Association appointed with reference to "the selection and nomenclature of dynamical and electrical units." In 1875 he prepared a volume of illustrations of the C. G. S. system (or centimeter-gram-second system) of units, adopted by this Committee, and of this volume the present work is substantially a second edition. It appears, however, in a much enlarged form, and under a different name. The importance to the physicist of having the many physical constants referred to a uniform series of fundamental units can hardly be over-estimated, and hence the great value of Professor Everett's book, in which this end is accomplished.

12. *Elementary Lessons on Sound;* by Dr. W. H. Stone. 191 pp. 12mo. London, 1879. (Macmillan & Co.).—The fundamental principles of Acoustics are fully and clearly stated and illustrated with numerous figures and practical examples. From them the author passes to the development of the theory of music, and explains it, so far as space permits, in a very clear and satisfactory manner. He makes use of the results of the more recent investigations in this field, and thus puts within the reach of the student much that would otherwise be inaccessible to him.

II. Geology and Mineralogy.

1. *On some points connected with the igneous eruptions along the Cascade Mountains of Oregon;* by Rev. Thomas Condon. (From a letter to J. D. Dana, dated Eugene City, Oregon, July 1, 1879.)—[The letter was written in reply to an inquiry respecting the continuity of the lavas of Mt. Hood and the Cascade Region with those of Mt. Adams and Mt. St. Helens, and relating to other points bearing on the extent of the eruptions southward along the Cascade range.—J. D. D.]

The Cascade range from Klamath River, south of the Columbia, to Mt. Rainier, on the north, has somewhat of the outline of a prostrate tree, far gone to decay. The main trunk is well represented by the main range; and at almost regular intervals along the whole line, we find, lying by its side, the remnants of its former limbs; not entire limbs now, but the knots that survive to represent them. Beginning at the north we find in the Simcoe Mountains, directly east of Mt. Adams, an evident outflow of eruptive material from that center; tilted and broken, yet in line. Twenty-five or thirty miles south of Simcoe Mountain, we find another such in the Klikitat Mountain; at the foot of which flows the Columbia River, and by whose help and guidance, the Columbia was enabled to penetrate and break through the range itself at the Cascades. This Klikitat Mountain is 2,000 feet high, and its beds are warped and tilted, showing that, like the Simcoe Mountain, it was subjected to the full measure of the violence that here closed the Miocene Tertiary. Thirty miles south of this is another elevation, known here as the Des Chutes Hill. This, too, is basalt, flexed and tilted, and broken, yet continuous; an evident outflow from the neighborhood of Mt. Hood.

Others may be traced farther south. Now all these hills have the following common characteristics: first, they are of eruptive origin; secondly, the dip is regularly away from the main range, from whose summit or sides they once flowed; thirdly, the dip they all have indicates a higher source of outflow than the present altitude of the range could give. They are just what they would be if the places they now occupy had once been the excavated valleys of streams of a higher level than our present ones, into which great lava streams flowed, displacing their waters, and thus transferring their eroding power from old ravines to the

softer sediments around them, till the ravine full of lava became a mountain, and its former banks deeper excavations. These transverse lines of hills as seen from a point fifty or sixty miles away show a fine series of accordant lines in perspective, very suggestive of similarity of origin.

At the close of the period, in the geology of the Cascade region, represented by the facts mentioned: First, there existed the main range, here running north and south, and at a much higher altitude than the present; second, a series of offshoots from the range less in altitude than the range itself; and third, a series of deep and extensive interspaces excavated in the older softer sediments, in relation to which these basaltic offshoots became future partitions.

Now one of the largest of these offshoots, situated between Mt. Hood and Mt. Adams, is the Klickitat Mountain, which breaks the continuity of all eruptions after the commencement of the Pliocene or thereabouts.

As to the history of the deeply excavated interspaces, we may take the one nearly east of Mt. Hood. The Des Chutes Hill, one of these offshoots already described, is its northern barrier, and we may make it our standard of record. That this excavation was once 2,000 feet deeper than it is now is proved by the two facts that, first, the Des Chutes River has cut its channel through its present filling of basalt without reaching the bottom, and secondly, that this great thickness of rock lies in undisturbed and unbroken level. Twenty-six to thirty distinct outflows may be counted in the section, at the crossing of the Des Chuttes River. This later basalt is dark in color, dense in structure, and easily distinguished from the basalt of the neighboring hill, which has a brown color and is lighter. These later outflows filled up this vast excavation, then spread eastward and northward till they reached the outlying elevations of the foothills of the Blue Mountains. A well defined belt of sedimentary rock marks the strictly eastern limit of this outflow along the line of Antelope Valley and the John Day River. The nearest centers of eruptive outflow, other than those of the Cascade Range here, would be from the western spurs of the Blue Mountains. The largest of these was an eruption from the neighborhood of Camp Watson. It flowed into what seems to have been the old meandering valley of the John Day River. It appears to have filled up the valley and set the waters to excavating a new one for themselves. This old valley full of basalt is now a mountain 1,200 to 1,500 feet above the plane. The mold in which its mass was cooled has long since been washed or quietly worn away. This Blue Mountain basalt can easily be distinguished from that of the Cascades. It is filled with granulations of a dark green pyroxene that gives its weathered surfaces a pustulated appearance.

The undisturbed basalts that have filled up those vast excavations constitute a *second* series of operations in the region.

The diminished eruptions of later times make another group of facts, and in the respective fields of Mt. Hood and Mt. Adams

they differ widely. It is as if the eruptions from Mt. Adams had ceased in times of strong currents of lava, while those of Mt. Hood continued till recent times, with less and less of dense materials, and a vast increase in showers of ashes, and outflows of volcanic mud.

The limited amount of examination I have myself given the summit line of the Cascade Range hardly entitles me to state how far the interval between Mt. Hood and Mt. Shasta is covered with eruptive rocks. But if I should judge from the materials brought down in the beds of its streams, and the rocks I have gathered at points where I have crossed the summit, I should say nearly the whole. This answer will not seem so improbable if we remember that our present snow peaks, Hood, Jefferson, The Sisters, Dimond, Scott and Pitt, are only a few of the volcanic vents between Hood and Shasta. These named only mark recent vents, and not even half of these. Many older vents have been covered up.

Two years ago I felt intensely interested in the examination of one of the more recent deposits of the Cascade Range, a short description of which I will add here. This deposit was the result of an immense shower of volcanic ashes. The point at which I crossed it is perhaps midway between Hood and Shasta. Of course these showers of ashes would drift eastward of the summit, for the prevailing winds there are westerly. We encountered them six or eight miles west of the summit. The volcanic ashes were evenly laid over the whole surface, like a covering of snow. East of the summit there was a marked increase in its quantity, so much so, that the sharp features of the older surface ceased to show themselves through it. We traveled over it for a distance of fifty or sixty miles, noticing that as we receded, from the Cascade Mountains, its materials were finer and its bulk less.

Eastward from Mt. Rainier this volcanic ash is everywhere mixed in large quantity with the Pliocene deposits of the Yakima Valley. Around Mt. Adams it is almost entirely absent. It abounds again eastward of Mt. Hood. Former lake widenings of the Columbia around The Dalles show this material stratified, and containing fine impressions of late Tertiary leaves, although deposited 200 feet above present waters. The amount of this volcanic ash, upon the eastern slope of the Cascade Mountains, is enormous, and helps conceal from the observer the rocks below. It has in it cementing material, so that a fall of rain upon it seems to have been sufficient to prevent its subsequent drifting.

2. *Bulletin of the U. S. Geological and Geographical Survey of the Territories* (under F. V. HAYDEN, as Geologist-in-charge.) Vol. V, No. 2. 180 pp. 8vo.—This new number of the Bulletin contains the following papers: on the Coatis, by J. A. ALLEN; on the present state of *Passer domesticus* in America, and Second Installment of American Ornithological Bibliography, by Dr. E. COUES, U. S. A.; on the Laramie Group of Western Wyoming and the adjacent regions, by A. C. PEALE; on Litho-

phane and new Noctuidæ, by A. R. GROTE; on certain Carboniferous fossils from Colorado, Arizona, Idaho, Utah and Wyoming, and Cretaceous corals from Colorado, together with descriptions of new forms, by C. A. WHITE; on the so-called Two-ocean pass (Plates 3 and 4), by F. V. HAYDEN; on the extinct species of Rhinoceratidæ of N. America and their allies, by E. D. COPE.

Mr. White here illustrates anew the fact that in the Western Territories the Subcarboniferous, Carboniferous and Permian, making together a series 4,000 or 5,000 feet thick, have no distinctive fossils, but instead, a commingling of the species elsewhere characterizing them; and only occasionally do new species in the lower beds point to a Subcarbonaceous age. It is also true, as a rule, that the Devonian and Upper Silurian are absent in all that great region;" and when all evidence of the presence of the Subcarboniferous fails, it is probable that this division is likewise "absent and from one and the same cause or from similar causes." As to the Permian, its *time* is probably represented by the upper strata, but no Permian fossils occur in it that do not also occur in the great mass of Carboniferous strata beneath. So far as invertebrate fossils are concerned, there is great uniformity throughout; and the prevailing characteristics as to fauna are those of the Coal-measures and especially the Upper Coal-measures of the Mississippi basin.

3. *On Stromatopora*, by H. J. CARTER (Ann. Mag. Nat. Hist., V, iv, 253, 1879.)—Mr. Carter, in this third article on Stromatopora, points out the close relation of these corals in structure to the coralla of Hydractinia and Millepora, and thus sustains the Hydroid affinities of the group. The paper is illustrated by a plate representing sections.

4. *Note on the Section by Mr. T. Nelson Dale on page* 293 *of this volume;* by Dr. S. T. BARRETT. (Communication dated Port Jervis, N. Y., Oct. 8, 1879.)—In the section by Mr. Dale, No. 5 is Hall's *Stromatopora Limestone*, and is the same as the *Favosite Limestone*, No. 2 (five feet thick), of my paper in vol. xiii, May, 1877, of your Journal. The name Favosite limestone is a synonym for Hall's Stromatopora limestone, and has long been dropped by me. No. 1, "Encrinal limestone," of the same paper, is undoubtedly the equivalent, or, more properly speaking, the continuation of Hall's Coralline limestone, which I think I have made out to be the equivalent of the Niagara limestone; at least, Whitfield recognized in it, at Nearpass Quarry, *Halysites agglomeratus*, *Favosites pyriformis*, *Cladopora seriata*, *Cyathophyllum Shumardi*, and *Rhynchonella pisa*, along with several Coralline limestone species. See this Journal, vol. xv, 1878.

5. *Geological Atlas of the State of Ohio.* Prepared by J. S. NEWBERRY, Chief Geologist, and E. B. ANDREWS, E. ORTON, M. C. READ, G. K. GILBERT, N. H. WINCHELL, F. C. HILL, Assistant Geologists. Published by authority of the Legislature of Ohio. 1879.—This atlas, published as embodying the results of the recent Geological Survey, is in six large sheets, and presents the distribution of the formations in colors. It is a very handsome

map in its style of publication, and of great interest geologically. Like the Wisconsin map and some other recent geological atlases, it is very large, much larger than the amount of detail upon it made necessary; and, therefore, those having to consult it might well say, too large. Still the science of the land is greatly indebted to the liberality of the State of Ohio, and to its geologists, for this and all the publications of the Survey.

Some points in the details of the part of the map relating to the section of the State under the charge of Professor E. B. Andrews are not in accordance with his conclusions; and since he had no part personally, as he states, in the preparation of the map, his proposed corrections, recently received for this Journal, are here annexed.

"(1.) The Lower Carboniferous limestone—the Maxville limestone of my reports—is represented on the map as having a continuous outcrop, forming, with but a single short break, a continuous belt more than four hundred miles long, around the sinuous margin of the Coal Measures. In my investigations in this district, where I have long lived, I have found the Lower Carboniferous limestone only in the few localities mentioned in the Reports; and always in limited patches. The limestone belt of the map crosses the paths of Professor Orton in Pike County, Professor M. C. Read in Licking County, and Professor Stevenson in Muskingum, but none of these field-workers saw it, and their detailed geological sections give no hint of it. (2.) The Conglomerate at the base of the Coal Measures reported by Professor Orton in Pike County, and by myself in Jackson County, is omitted from the map. (3.) According to the map, the Waverly rocks, for a considerable distance, rest upon the Silurian rocks of the Cincinnati uplift without any intervening Devonian Black shale—the Huron shale of Dr. Newberry. This is not far from the eastern line of Adams County. My report for 1869, and the preliminary map give the belt of Black shale in its proper location, for 'it is finely exposed,' to quote from the report, 'in the Ohio River hills in the neighborhood of Rockville, Adams County, and in nearly all the hills which range to the north.' The final map represents the existence of the Black shale at Portsmouth and in the valley of the Scioto River above, where my searches only revealed Waverly rocks; but if there, the shale, rising to the westward, passes over a hilly mass of Waverly sandstone, and according to the map never comes out in any western outcrop."

6. *Geological Survey of Canada: Mesozoic Fossils*, Volume I, Part ii, *on the Fossils of the Cretaceous Rocks of Vancouver and Adjacent Islands in the Strait of Georgia;* by J. F. Whiteaves, F.G.S., Palæontologist to the Survey. 100 pp. 8vo, with 10 lithographic plates. Montreal, 1879.—The Cretaceous fossils are from the southeastern part of Vancouver Island, and pertain to two Coal-fields, the Comox and the Nanaimo. In the former, the thickness of the whole series is 4,912 feet, and that of the productive Coal-measures, 739½ feet; while in the latter, the whole

‹ness is 5,266 feet, and that of the productive measures, 1,316

On the Structure and Affinities of the Tabulate Corals of the ‹eozoic *Period, with critical descriptions of Illustrative Spe-*‹; by H. ALLEYNE NICHOLSON, Prof. Nat. History, Univ. St. ‹rews. 338 pp. 8vo, with 15 plates. Edinburgh and London. ‹. (William Blackwood & Sons.)—Professor Nicholson has ‹opportunities in America as well as in his own land for the ‹y of fossil corals, and has devoted much of his time for several ‹s to the subject. The present work is the fruit of a large ‹unt of careful study with the aid of microscopic sections, and ‹y interesting results are brought out, as is exhibited on the ‹ral lithographic plates. On account of the abundance in this ‹try of the corals treated of, the critical character of the work, ‹the comparisons made of American and European species or ‹eties, the work has special interest for both hemispheres. He ‹es, as the general result of his investigations, that his labors ‹oborate the views of Verrill and Landström as to the necessity ‹bolishing the "Tabulata" as a separate division, and lead to ‹conclusion that under this old name there are included at least ‹ve distinct groups of corals.

The Journal of the Cincinnati Society of Natural History, ‹ii, No. 1, April, 1879.—Contains: Remarks on the genus ‹*rocrinus*, by A. G. WETHERBY; Descriptions of new species ‹ossils from the Lower Silurian about Cincinnati, by E. O. ‹ICH; Remarks on the Kaskaskia Group and descriptions of ‹species of fossils from Pulaski Co., Ky., by S. A. MILLER; ‹logue of plants growing in the vicinity of Cincinnati, by J. ‹AMES. It is illustrated by two Plates, 7 and 8; and the first ‹ies illustrated on plate 7 is the remarkable Crustacean, *Eno-*‹*ra balanoides*, named by Meek, but first rightly understood ‹described by Mr. Wetherby. The price of the number is ‹60 cents; of the volume $2.00.

On the Old Red Sandstone of Western Europe, by ARCHI-‹ GEIKIE, F.R.S., Director of H. M. Geological Survey of ‹land, etc. Part I, 108 pp. 4to. From vol. xxviii, Trans. Roy. ‹Edinb., 1878.—This memoir contains a general review of the ‹ connected with the "Old Red Sandstone," largely from per-‹l investigations by the author, and a discussion of the changes ‹he physical geography of Western Europe which took place ‹een the close of the Upper Silurian and the commencement of ‹Carboniferous period. It is illustrated by maps and sections.

‹. *Outlines of Field Geology*, by ARCHIBALD GEIKIE. 216 pp. ‹o. London, 1879. (Macmillan & Co.)—This volume is intended ‹he guidance of the learner in field geology, and will be found ‹nvenient manual. Professor Geikie's own labors in the field ‹le him to give instruction of much value on all points connected ‹ the subject. Some will wish that it were more extended.

. *Reports and Awards, Group I, International Exhibition,* ‹, edited by Francis A. Walker, Chief of the Bureau of

Awards. 486 pp. 8vo. Philadelphia, 1878. (J. B. Lippincott & Co.).—Group I was that including ores and mineral products, building stones, marbles and other useful and ornamental stones; also implements and machinery used in connection with the same, and various statistics relating to them. The volume contains reports by J. S. Newberry, W. S. Keyes, J. Lowthian Bell, T. Sterry Hunt, Frederick Prime, Jr., A. L. Holley, J. M. Safford, John Fritz, M. Addy, G. C. Broadhead, E. Althaus, L. Simonin and others; and in them there is a large amount of valuable information.

12. *Mémoire sur la Structure et la composition Minéralogique du Coticule*, par A. RENARD, S. J., Conservateur au Musée Royal d'Histoire Naturelle de Belgique. 44 pp. 4to. Brussels, 1877. (Mèm. Cour. Acad. Roy. Sci., Belgique, vol. xli.)—The author of this memoir proves by his investigations, that the fine yellowish whetstone, making the best of hones for razors, which is quarried at Salm-Château, Lierneux, Sart, Bihain and Recht, in Belgium, consists of massive manganesian garnet. It occurs in beds four to forty inches thick, in a slate, as a part of the slate formation. The characters of the beds are described in detail in the memoir. The composition of the whetstone of Recht, according to Dr. von der Mark (1) and M. Pufal (2), is as follows:

	SiO_2	TiO_2	$\overline{Al}O_3$	$\overline{Fe}O_3$	FeO	MnO	MgO	CaO	Na_2O	K_2O	
1.	48·73	*tr.*	19·38	2·42	....	21·71	....	0·28	1·57	3·51	loss 2·40, F tr=99·88
2.	46·52	1·17	23·54	1·05	0·71	17·54	1·13	0·80	0·30	2·69	H_2O 3·28, CO_2 0·04, P_2O_5 0·16, S 0·18, organic matter 0·02=99·13

The slate, which is feebly metamorphic, is a damourite slate or schist; and the potash of the analyses is attributed to the presence of this mica in the whetstone. In microscopic sections the rock appears to consist of very minute granules—more than 100,000 in a millimeter-cube, and they show sometimes the form of the rhombohedron. In view of the form and the composition the conclusion is reached that the whetstone is a compact manganesian garnet or spessartine. This is sustained also by the specific gravity, which is 3·22, according to M. Pufal.

The occurrence of garnet in the "phyllade oligistifère" of Recht, an associated rock, was previously recognized by Zirkel.

M. Renard examined whetstones of other localities without finding a similar constitution; among them, the whetstone of Arkansas, which proved to be wholly quartzose, as had been shown by the analysis of Owen. The memoir is illustrated by a colored plate of microscopic sections.

13. *Report on the Minerals of some of the Apatite-bearing Veins of Ottawa County, Quebec, with notes on miscellaneous Rocks and Minerals* (1878); by B. J. HARRINGTON, Ph.D. 52 pp. 8vo. Montreal, 1879. (Geol. Survey of Canada).—Dr. Harrington describes the apatite deposits of Ottawa County as occurring most commonly in connection with rocks, which consist almost exclusively of pyroxene, though quartz and orthoclase

e often present, as also mica and minute garnets. When the rroxene is the principal mineral the rock shows little trace bedding, but is often much jointed and sometimes has the ›pearance of massive eruptive rock. Other rocks of the same ıosphate region are gneisses, quartzites, and crystalline limeones. The apatite occurs in many cases in connection with rroxene in what are regarded as true fissure veins. These veins ıve sometimes a banded structure, but in general are characterized r a want of regularity; the apatite crystals often show proof of ıving been broken and re-cemented. At some localities the ›atite is chiefly in crystals, often of great size, "a foot or more diameter and several feet in length, and weighing hundreds of ›unds." The edges of the crystals are often rounded. At other calities, on the other hand, it is almost wholly massive, varying ›m compact or crypto-crystalline to coarse-granular; a friable ccharoidal variety is common. One mass of a sea-green variety described which "as exposed measured nearly twenty feet across, d in the whole thickness was apparently free from other minals with the exception of a few crystals of pyroxene and mica." ıe color of the mineral varies through many shades of green to y-blue, red, brown, yellow and white. The specific gravity of dark-green glassy crystal from the Grant Mine in Buckingham as found to be 3·2115.

A list of thirty species occurring in the apatite-veins is given, me of the most important of which are: calcite, quartz, pyroxene, ›rnblende, phlogopite, garnet, black tourmaline, titanite, zircon, thoclase, scapolite. Of the associated minerals the most abundant pyroxene, the commonest variety being an aluminous sahlite, but light-colored variety is also common. An analysis of a blackisheen crystal afforded:—

	SiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	CaO	MgO	ign.
=3·385	51·28	2·82	1·32	9·16	0·33	23·34	11·61	0·17=100·03

ther varieties also occur, sometimes in crystals of large dimensions. The pyroxene is often partially or wholly altered to uralite. The ange appears to have begun at the surface of the crystal and adually extended inward; at the surface the hornblende prisms e mostly parallel to the vertical axis, within they run in all direc›ns and are sometimes in radiating groups. One crystal had a nter of glassy pyroxene (A), surrounded by a dull pale material ›), and this by an aggregation of hornblende (uralite) prisms (C). nalyses of these three portions afforded:—

SiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	CaO	MgO	K_2O	Na_2O	ign.
50·87	4·57	0·97	1·96	0·15	24·44	15·37	0·50	0·22	1·44=100·49
50·90	4·82	1·74	1·36	0·15	24·39	15·27	0·15	0·08	1·20=100·06
52·82	3·21	2·07	2·71	0 28	15·39	19·04	0·69	0·90	2·40= 99·51

ıe specific gravity was for A=3·181, for B=3·205, and for =3·003. The change in composition from A to C is seen to nsist principally in the loss of lime and gain in magnesia, though ere is also a loss of alumina and slight gain in alkalies.

Dr. Harrington also discusses the relations of the phosphate

region of Ottawa County to the Apatite-bearing veins of Norway described by Brögger and Reusch (ZS. G. Ges., xxvii, 646, 1875). There is a general similarity in the associated minerals and in other respects, but the apatite in Norway is described as occurring in an eruptive rock (gabbro), the crystals having been rounded by partial fusion. The latter part of Dr. Harrington's Report contains descriptions and analyses of a manganiferous calcite, of chrysolite, of some diorites near Montreal, and other points of interest. E. S. D.

14. *Die Pseudomorphosen des Mineralreichs; vierter Nachtrag* von Dr. J. REINHARD BLUM. 212 pp. 8vo. 1879. Heidelberg. (Carl Winter).—Sixteen years have passed since the preceding appendix (the third) to his important work on the Mineral Pseudomorphs was published by Professor Blum. The many friends of the veteran author will rejoice that his life and strength have been spared so long, and that he has been able to add another important contribution to a branch of mineralogical science which owes its distinct existence to his labors. The general recognition of interest attached to the study of the changes in the chemical composition of minerals is shown by the large number of published researches which have had this as their subject; the number of pseudomorphs described in the original work (1843) was 164, and this has since been increased to 436. The present volume contains all the cases which have been described since the appearance of the last appendix. The 200 pages devoted to them is a proof of their number and the care with which the author discusses them. E. S. D.

III. BOTANY AND ZOOLOGY.

1. *Electrical Currents in Plants.*—In a notice of the action of *Dionæa* and other irritable plants, published soon after the popular exhibition of the electrical phenomena attending the movement, said to be similar to those attending the contraction of a muscle, we threw out the suggestion that these remarkable phenomena were not unlikely to be explained away. The suggestion was founded on some investigations and trials made in the botanical laboratory of Harvard University by Professors Goodale and Trowbridge, which were never published, there being an intention to follow them up later. It appears that Kunkel has taken up this investigation and reached the same result, in the laboratory at Würzburg. His paper,* as abstracted by Micheli in Arch. Sci. Phys. and Nat. for Sept., 1879, announces that he does not admit the existence of any electrical tension in the intact tissues of the plants in question, but he concludes that the currents developed upon spontaneous movement, and similarly upon artificial curvature, are due to movements of the liquid in the cells caused by mere contact with the electrodes, or by either active or passive movements of the organs. A. G.

* Ueber electromotorische Wirkungen an unverletzen lebenden Pflanztheilen.

2. *Adnotationes de Spiræaceis*, auct. C. J. Maximowicz. (Seorsim impressæ ex Actis Horti Petropolitani, tom. vi.) Petropoli, 1879, pp. i–xii, and 105–261, 8vo.—This is one of the most considerable botanical papers of the time. It will require to be carefully weighed before its conclusions are either rejected or adopted. Dr. Maximowicz separates the *Pomaceæ* from the *Rosaceæ* (these including the *Amygdaleæ* or *Pruneæ*), and, reducing the value of adhesion of calyx-tube with the gynœcium (to which we cannot in principle object), refers his *Spiræaceæ* to the order *Pomaceæ*, and divides the order into two families, *Pomaceæ* proper, with a succulent-fleshy calyx-tube which is usually connate with the carpels, and *Spiræaceæ* with an herbaceous calyx-tube, free from the dehiscent carpels. The order thus constituted is regarded as intermediate between *Rosaceæ* and *Saxifragaceæ*. The Linnæan *Spiræa*, which must be allowed to be composite and which included four Tournefortian genera, is distributed among the tribes of the first two orders.

The *Spiræaceæ* are divided into several tribes: the *Spiræeæ*, with carpels when isomerous with the sepals alternate with them, containing *Aruncus*, *Eriogynia* (preferred to *Lutkea*, though possibly, and we suppose without much doubt, not quite so old), *Spiræa* (of the sections *Petrophytum*, *Chamædryon*, and *Spiraria*), and *Sibiræa* (*S. lævigata* L.); these have little or no albumen and thin coat to the seed: *Neillieæ*, differing in having a smooth and stony seed-coat and very distinct albumen (*Physocarpus*, *Neillia*, *Stephanandra*, under which arrangement the separation of the first two seems most proper): *Gillenieæ*, with the carpels opposite the sepals when of the same number, otherwise nearly with the characters of the preceding; this includes *Sorbaria* (Lindley's *Schizonotus*), *Chamæbatiaria* (horrid name for a genus, taken from the sectional name given by Professor Porter to *Spiræa Millefolium* Torr.), *Spiræanthus*, of a single Siberian species, and *Gillenia*; finally the *Quillaieæ*, with winged seeds, the first genus of which is *Exochorda*. To *Rosaceæ*, as here limited, Maximowicz refers *Filipendula* (including *Spiræa filipendula*, *Ulmaria lobata*, and the like), excluded from the *Spiræeæ* and included in the *Sanguisorbeæ* on account of their indehiscent and one-seeded (biovulate) carpels; and *Holodiscus* of Koch (composed of *Spiræa discolor* and the Andine *S. argentea*), which is referred to the *Potentilleæ*, along with *Cercocarpus*, *Cowania*, and *Fallugia*, with the remark that its biovulate achenia ally it to the *Rubeæ*. Of *Rubus* it is said that the seeds are distinctly albuminous; and *Kerria*, *Neviusia*, and *Rhodotypus* are placed among the *Rubeæ*. A. G.

3. Boissier, *Flora Orientalis*, vol. iv, pp. 1276, 8vo.—This Oriental Flora, as is well known, covers the ground from Greece to Egypt, and to the boundaries of India and of Asiatic Russia. This fourth volume, completed early in 1879 by the publication of the second fasciculus (of almost a thousand pages), contains the *Corollifloræ* and the *Monochlamydeæ*, in other terms the Gamopetalous and Apetalous Exogens. We may therefore expect that

the indefatigable author will ere long complete this laborious and noble work. These fifteen or twenty years will then be distinguished by the production of the *Flora Australiensis* and the *Flora Orientalis*. Would that the Flora of North America were added to the number. A. G.

4. *Sulla Diffusione dei Liquide Colorati nei Fiori*; by Professor P. A. SACCARDO.—The writer gives an account of his experiments in immersing cuttings of flowering plants in different coloring fluids, and concludes by saying that aniline-green is especially favorable for staining not only the vessels but the parenchyma of flowers. The paper is followed by a sheet on which actual specimens of stained petals serve as illustrations, with a pleasing effect. W. G. F.

5. *Neue Beobachtungen über Zellbildung und Zelltheilung*; by Professor ED. STRASBURGER.—Nos. 17 and 18 of the Botanische Zeitung contain an important article by Strasburger. It had generally been admitted by botanists, including Strasburger himself, that the endosperm was formed in the embryo-sack by free-cell formation. Strasburger now says that this is not true, and that there is no formation of free nuclei in the embryo-sack; he having in previous papers shown that the embryonal vesicle and antipodes do not arise by a free-cell formation. As in the case of the two last named structures, the endosperm-cells are formed by a division of the nucleus of the embryo-sack. *Myosurus minimus* is especially adapted for the study of the subject, owing to the elongated receptacle. Strasburger also states that in the *Ascomycetes* the spore-formation is not preceded by a dissolving of the nucleus of the ascus followed by the formation of free nuclei, but that the original nucleus divides to form the nucleus of each spore. He makes the sweeping assertion that a free formation of nuclei as the initial stage of cell-formation cannot be assumed (in plants), unless we conceive such to be the case in the mother cells of the spores in *Anthoceros* and in those of the macrospores of *Isoëtes*, in which cases observation is obscured by the presence of granular accumulations in the cells. He does not deny, however, that free nuclei may be formed in some instances, but only that it does not accompany cell-formation. In *Spirogyra*, for instance, the spore has at first no nucleus but one is formed at the time of germination. The same is true of the swarm-spores of *Ulothrix*.

The last part of the paper treats of the different arrangements of nuclear plates and nuclear threads, as a comprehensive distinction between the division of animal and vegetable cells in the formation of what Strasburger calls the cell-plate in plants. This is dependent upon the presence of a cellulose membrane in plants. It may be objected, however, that no cellulose membrane can be detected in many plant-cells. W. G. F.

6. ARNOLD ARBORETUM.—*Prof. Charles S. Sargent* is appointed Professor of Arboriculture in Harvard University, along with the directorship of the Arnold Arboretum at the Bussey Institution. He now devotes himself entirely to the arboretum, resigning the

charge of the Botanic Garden at Cambridge, which is assumed by Professor Goodale.

7. Prof. J. G. AGARDH has resigned the chair of Botany at the University of Lund. *Dr. F. W. C. Areschoug* has been appointed his successor.

8. P. VAN TIEGHEM is appointed Professor of Vegetable Anatomy and Physiology at the Jardin des Plants, Paris, in the chair vacated by the death of Brongniart some years ago.

9. Dr. ODOARDO BECCARI succeeds to the late Prof. Parlatore as Professor of Botany and Director of the Gardens at Florence.

10. *Die Spongien des Meerbusen von Mexico*, von OSCAR SCHMIDT. 4to, 1st Heft, with four plates. Jena, 1879.—This memoir relates to sponges collected by the dredging expedition of the steamer Blake, under the supervision of Alexander Agassiz. The excellent plates illustrate the forms and spicula of many species.

IV. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Catalogue of Scientific Serials*, from 1633 to 1876, by SAMUEL H. SCUDDER. 358 pp. 8vo. Cambridge, Library of Harvard University, 1879.—This catalogue embraces the Transactions and Bulletins or Proceedings of Learned Societies in the Natural, Physical and Mathematical sciences of all countries, as well as independent journals. It has been prepared, under the auspices of the Harvard College Library, by Mr. Scudder, assistant Librarian; and it is a result of a vast amount of labor and great care. All persons interested in the progress of science will find it an invaluable companion. The titles are arranged alphabetically under the heads of each of the States or Countries from which they were issued, and, in addition, there are Indexes of titles and of places of publication. Harvard Library has met the expense of publication, with the expectation that the demand for the volume will refund the outlay, and with the promise that if so far remunerated, this shall be the beginning of a series of "works such as may be properly undertaken by a public Library, and do not offer inducement for commercial speculation;" and it will be greatly for the benefit of learning in the land, that in this there should be no disappointment.

2. *A Sketch of Dickinson College*, Carlisle, Pennsylvania; by CHARLES F. HIMES, Ph.D., Professor of Natural Science. 156 pp. 12mo, illustrated by engravings, and by photographs executed in the Laboratory. Harrisburg, 1879.—*The History of Dickinson College*, has a general interest because of the connection with its scientific department, the second year after its establishment, in 1811, of Thomas Cooper, the friend, and companion over the sea, of Priestley—a man of wide range of learning, of great chemical knowledge for his time, and of strong opinions on all subjects. Prof. Himes's "Sketch," contains, among its photographic plates, one with figures of the air-gun and burning glass which, along

with a telescope, Dr. Cooper purchased of Priestley for the college, by authority of its Board of Trustees, and which are now among its physical apparatus. It appears further from the sketch that it was while in this position that Dr. Cooper revived the "Emporium of Arts and Sciences," one of the earliest of American Scientific Journals, and gave it "a high scientific character," and issued also an edition of Accum's Chemistry in two volumes. Thus the scientific department of Dickinson was one of the earliest established in the country, and behind no other in the learning and ability of its chief instructor. The Journal, a bi-monthly of 150 pages, came to an end in 1814—the long delay of the final volume being explained by the fact of "the printers serving their country as volunteers." Dr. Cooper left his chair in 1815, and became afterward President of South Carolina College. Prof. Baird, a graduate of Dickinson College, now Secretary of the Smithsonian Institution, was made its Professor of Natural History in 1848, and held the office until 1850, when his connection with the Smithsonian Institution began under Professor Henry.

3. *Ephemeris of the Satellites of Mars for October and November*, 1879.—The ephemeris on pages 317, 318 of this volume, was prepared for the Journal by Henry S. Pritchett, Assistant Astronomer in the United States Naval Observatory at Washington.

4. *Scientific Lectures;* by Sir JOHN LUBBOCK, Bart., Vice President of the Royal Society, etc. 188 pp. 8vo. London, 1879. (Macmillan & Co.).—This volume contains six lectures by Sir John Lubbock: on Flowers and Insects, on Plants and Insects, on the Habits of Ants, Introduction to the Study of Prehistoric Archæology, and an Address to the Wiltshire Archæological and Natural History Society. They are in part the result of original research; and although, as the Preface says, "the little book does not contain anything new to those who have specially studied the parts of science with which it deals," many of the facts are among the most remarkable in science, and make instructive and attractive reading for all inquiring minds. Further, they are well calculated to cultivate an inquiring spirit in the mind of those who have thought themselves indifferent to the study of nature.

5. *Shell Mounds of Omori*, by EDWARD S. MORSE, Prof. Zool. Univ. Tokio, Japan. Mem. Univ. Tokio, vol. i, part 1, 1879. 36 pp. large 8vo, with 18 plates.—Professor Morse gives evidence that the mound-builders were cannibals either from an emergency or by preference. The implements obtained are made of stone, horn, bone and pottery, but there are no arrow-heads or spear-points of flint or other material, and few of the relics are of stone.

Report of Work of the Agricultural Experiment Station, Middletown, Conn., 1877–8. 174 pp. 8vo. Hartford, 1879.

THE

AMERICAN

JOURNAL OF SCIENCE AND ARTS.

[THIRD SERIES.]

ART. L.—*On Photographing the Spectra of the Stars and Planets*; by HENRY DRAPER, M.D.

[Read before the National Academy of Sciences, Oct. 28th, 1879.]

FOR many years it has seemed probable that great interest would be attached to photographs of the spectra of the heavenly bodies, because they offer to us conditions of temperature and pressure that cannot be attained by any means known at present, on the earth. The especial point of interest is connected with considerations regarding the probable non-elementary nature of the so-called elementary bodies. There has long been a suspicion in the minds of scientific men that one or more truly elementary bodies would be found from which those substances which have not as yet been décomposed, are formed. The recent publications of Lockyer have attracted particular attention to this topic.

The most promising laboratory processes for accomplishing the dissociation of our present elements depend upon the action of heat, especially when accompanied by electrical influences, and upon relief of pressure. But the temperature we can employ is far below that found in the stars, which is comparable only with the heat of our Sun, and when in addition the application of heat is restricted by the narrow range of circumstances under which we can also reduce the pressure, complete success seems to be impracticable in the laboratory.

But in the stars, nebulæ and comets there is a multitude of experiments all ready performed for us with a variety of conditions of just the kind we need. It remains for us to observe

and interpret these results, and this is the direction I have sought to pursue.

There is but one mode of investigation that can add materially to the knowledge Astronomy has given us of the heavenly bodies; that is the spectroscopic. This in its turn is capable of a subdivision into two methods, one by the eye, the other by photography. Each of these has its special advantages and each its defects. The eye sees most easily the middle regions of the spectrum, and can appreciate exceedingly faint spectra; by the aid of micrometers it can map with precision the position of the Fraunhofer lines, and by estimation it can with tolerable accuracy approximate to the relative strength, breadth and character of these lines. The character of the spectrum lines is however of great value for the purposes we are now speaking of, and the greatest precision is needed. Photography, on the other hand, as applied to faint spectra, deals mainly with the more refrangible region, and cannot at present be employed in stellar work below the line F. Fortunately there is no break in the spectrum between the place where the eye leaves off and photography begins, and hence the two methods lend one another mutual assistance. The photograph when suitably accommodated with a standard reference spectrum from some known source, gives valuable indications as to the positions and all the peculiarities of the lines.

But the application of photography to the taking of stellar spectra is surrounded by obstacles. These are partly due to the small quantity of light to be dealt with, and partly to the fact that it is necessary to overcome the motion of the earth and other causes, such as atmospheric refraction, which seem to make a star change its place continually. The exposures of the sensitive plate require to be sometimes for two hours, even with a large telescope, and if during that time the image of the star at the focus of the telescope has changed place $\frac{1}{300}$ of an inch the light no longer falls on the slit of the spectroscope. The changes of the earth's atmosphere in regard to photographic transparency as well as by fog also offer impediments, and promote the chances of failure. There is often a yellow condition of the air, which may increase the length of exposure required forty times or more.

It will, from what has been said above, be readily perceived that a research such as this consumes a great deal of time, in fact these experiments and the preparations for them have extended over more than twelve years. A large telescope is required, and for many reasons the reflector at first seems most suitable. Recently, however, I have found that the refractor has also some special advantages.

In 1866 I had already constructed a silvered glass reflector

of 15½ inches aperture, which was commenced in 1858, and had taken with it many hundreds of photographs of the Moon. But as the mounting had been contrived for lunar photography and to avoid the Moon's motion in declination, the instrument was not suitable for the spectroscopic work contemplated. A reflector of twenty-eight inches aperture was therefore commenced in 1866, and in 1871 it was ready for use.

On May 29th, 1872, my first photograph of the spectrum of a star was taken, the spectrum of Vega being photographed by the aid of a quartz prism. At this time I did not happen to know that Dr. Huggins, who is so distinguished for his thorough and accurate researches on the visible portion of the spectra of the heavenly bodies, had already made some attempts in this direction, as is shown by the following paragraph from the Transactions of the Royal Society for 1864: "On the 27th of February, 1863, and on the 3d of March of the same year, when the spectrum of Sirius was caused to fall upon a sensitive collodion surface an intense spectrum of the more refrangible part was obtained. From want of accurate adjustment of the focus, or from the motion of the star not being exactly compensated by the clock movement, or from atmospheric tremors, the spectrum, though tolerably defined at the edges, presented no indications of lines. Our other investigations have hitherto prevented us from continuing these experiments farther; but we have not abandoned our intention of pursuing them."

During August, 1872, I took several photographs of the spectrum of Vega, and these showed four strong lines at the more refrangible end of the spectrum, the least refrangible being near G. On pursuing the subject and seeking to ascertain what substances gave rise to these lines, it became obvious that a photographic study of this part of the spectrum for the metals and non-metals was necessary to interpret the results. This of course opened out a large field for experiment, requiring many years for its study, and hence, as several physicists were engaging in the study of the spectra of the metals, I concluded to discontinue the experiments commenced in 1870 on the spectra of the metals and to confine the investigation mainly to the non-metals. The initial step was, however, to obtain a fine photograph of the normal solar spectrum, so that the wave lengths of the lines up to O [wave length 3440] might be determined with precision.

In the spring of 1873 I published a paper on the diffraction spectrum of the Sun, illustrated by a photograph embracing the region from wave length 4350 near G to 3440 near O, and in the fall of the same year took photographs of the spectra of several non-metals, notably nitrogen, carbon, and oxygen.

The experiments were interrupted, in the spring of 1874, by going to Washington to superintend the photographic preparations for the United States observations on the Transit of Venus.

Since that time my experiments have been divided into two parts, an astronomical portion occupying principally the summer season, and a laboratory portion during the rest of the year. The former consisted of photographs and observations on the spectra of the stars, planets and sun; the latter of photographic work on the spectra of the elements and particularly the non-metals, and has led to the discovery of oxygen in the sun.

In 1876, Dr. Huggins published a note in the Proceedings of the Royal Society, accompanied by a wood-cut of the spectrum of Vega, with a comparison solar spectrum. Seven lines were observed in the spectrum of Vega. In the summer and autumn of 1876 I made several photographs of the spectra of Vega, *α* Aquilæ and Venus, and sent a note concerning them to this Journal.

Since that time Dr. Huggins has pursued the subject actively in spite of the London atmosphere, and has attained very fine results, which I had the pleasure of seeing at his observatory last spring. These he is preparing to publish shortly. In my observatory photographs have been taken of the spectrum of Vega, Arcturus, Capella, *α* Aquilæ, Jupiter, Mars, Venus, the Moon, etc. Recently the plan has been to have a comparison solar spectrum on every plate, derived either from the diffused light of our atmosphere or from the Moon or from Jupiter. In this way no difficulty in determining the wave lengths of the lines is encountered, and the changes produced by our atmosphere are eliminated. The telescope and spectroscope are now in good working order, but to secure the requisite degree of precision of movement it has been necessary to make seven different driving clocks before a satisfactory one was attained.

It has been remarked that on account of the faintness of the light of stellar spectra, prolonged exposures of the sensitive plate are required. In former times when the dry processes of photography were much less sensitive than the best wet plates, the exposure was limited by the length of time the plate could be left in the camera without being stained by drying. But now, since the gelatino-bromide process has been introduced, this obstacle has been removed and a sensitive plate is sometimes exposed two hours to the spectrum of a star and then almost an hour to Jupiter for the comparison spectrum. The best, and most sensitive, gelatine plates I have used are those made by Wratten & Wainwright of London; Dr. Huggins was good enough to call my attention to them.

It is not worth while to describe the various forms of spectroscope that have been employed in the last ten years, quartz, Iceland spar, hollow prisms and flint glass have been the materials, and they have been sometimes direct vision and sometimes on the usual angular plan. Gratings on glass and speculum metal given to me by Mr. Rutherfurd have been tried. The length of spectroscope has been sometimes twenty-eight feet and sometimes not as many inches.

The especial spectroscope for stellar work that is now on the telescope is intended to satisfy the following conditions: 1st, to get the greatest practicable dispersion with the least width of spectrum that will permit the lines to be seen; 2nd, to use the entire beam of light collected by the 28-inch reflector or 12-inch achromatic without loss by diaphragms; 3d, to permit the slit to be easily seen so that the star may be adjusted on it; 4th, to avoid flexure or other causes that might change the position of the spectrum on the sensitive plate in pointing the telescope first on one and then on another object; 5th, to admit of observing the spectrum on the sensitive plate at any time during an exposure without risk of shifting or disarrangement. The dispersion is produced by two heavy flint prisms which are devoid of yellow color; the telescopes are about six inches in focal length and the slit has a movable plate in front of it, enabling the operator to uncover either the upper or the lower portion at will.

During the past summer this spectroscope has been used with the Clark refractor of 12 inches aperture, partly because the 28-inch reflector has been kept unsilvered since it was used in taking photographs of the Transit of Mercury, on account of its employment in certain experiments on the Sun. Moreover, there is an advantage possessed by the refractor for this work which does not appear at first sight. Naturally one supposes that a reflector which brings all the rays from the star, no matter what their refrangibility, to a focus in one plane, would be best, because when the slit is put in that plane it is equally illuminated by rays of all refrangibilities, and the spectrum will be parallel-sided in its whole length. On the other hand a refractor is not achromatic, for the violet end of the spectrum comes to a focus either inside or outside of the plane of the rays in the middle of the spectrum, and in observing the spectrum it is not parallel-sided. This peculiarity was used by Mr. Rutherfurd to enable him to correct a telescope lens for the ultra violet rays. It is easy therefore with a refractor so to adjust the position of the slit that you may have a spectrum tolerably wide at F and G, and which gradually diminishes in width toward H, and finally becomes almost linear at M. Now as the effect of atmospheric absorption on

the spectrum increases as you pass from G toward H and above H, by diminishing the width of the spectrum you can in some measure neutralize the effect, and at one exposure obtain a photograph of nearly uniform intensity from end to end, though it is of variable width. If it were not for this it would be necessary to have the spectrum over-exposed at G in order to be visible above H, or else to resort to an elaborate diaphragming which is difficult.

It is my intention next season to return to the use of the 28-inch reflector, because it collects nearly five times as much light as the 12-inch does, after making allowance for the secondary mirror. Of course in a large reflector the difficulties of flexure and instability of the optical axis are much increased, and keeping a star on the slit will be troublesome, especially as the magnifying power on the image is about 50.

As to the results obtained, it has already been mentioned that the spectra of several stars and planets have been photographed. The subject of planetary spectra will be reserved for a future communication. A preliminary examination at once shows that these stellar spectra are divisible into two groups: first, those closely resembling the solar spectrum, and second, those in which there are relatively but few lines, and these of great breadth and intensity. The photographs of the spectra of Arcturus and Capella are so similar to the solar spectrum, that I have not up to the present detected any material differences. But on the other hand, the spectra of Vega and α Aquilæ are totally different, and it is not easy without prolonged study and the assistance of laboratory experiments to interpret the results, and even then it will be necessary to speak with diffidence. I have not as yet obtained any stellar spectrum photographs belonging to the third and fourth groups of stellar spectra as described by Secchi. These, if obtainable, will aid materially in discussing the whole subject, but unless a star passes near the zenith it is hard to make a fair study of its spectrum by photography, because atmospheric absorption in the ultra violet region increases rapidly as the altitude decreases. In the case of the Sun, I have found that at sunset the exposure necessary to photograph the spectrum above H, is often 200 times as long as at midday.

In the case of the spectrum of Vega when examined by the eye, the lines C, F, near G and *h*, are readily visible, but lines such as D and *b* are relatively faint. It is clear then, that hydrogen exists to a large extent in the atmosphere of that star. But on examining the photograph of its spectrum it is evident that other lines just as conspicuous as the hydrogen lines, are present. One of these corresponds in position and character to H_1 and seems to coincide with a calcium line. It appears

to me, however, that the evidence of this coincidence is not complete.

In attempting to reason from these photographs as the matter now stands, it is necessary to try at every step farther experiments in order to find out whether the facts agree with hypothesis, and it is this very condition of affairs that gives hopes of results valuable in their bearing on terrestrial chemistry and physics. In the photographs of the spectrum of Vega there are eleven lines, only two of which are certainly accounted for, two more may be calcium, the remaining seven, though bearing a most suspicious resemblance to the hydrogen lines in their general characters, are as yet not identified. It would be worth while to subject hydrogen to a more intense incandescence than any yet attained, to see whether in photographs of its spectrum under those circumstances any trace of these lines, which extend to wave length 3700, could be found.

It is to be hoped that before long we may be able to investigate photographically the spectra of the gaseous nebulæ, for in them the most elementary condition of matter and the simplest spectra are doubtless found.

ART. LI.—*Abstract of Observations upon the Artificial Fertilization of Oyster Eggs, and on the Embryology of the American Oyster*; by W. K. BROOKS, Associate in Biology, Johns Hopkins University. (Notes from the Biological Laboratory of the Johns Hopkins University).

ALL the writers upon the development of the oyster, from Home (Phil. Trans., 1827), to Möbius (Austern und Austernwirtschaft, 1877), state that the eggs are fertilized inside the shell of the parent, and that the young are carried inside the mantle cavity until they are provided with shells of their own: that they leave the parent in a somewhat advanced state of development, and that their free-swimming life is of short duration and lasts only until they find a suitable place to attach themselves.

Misled by these statements, which do not apply to our species, I opened a number of oysters during the summer of 1878, and examined the gills and the contents of the mantle-chambers for young, but found none, and concluded that the time during which the young are carried by the parent must be so short that I had missed it. I undertook the same investigation this May, with the determination to examine adult oysters for young every day during the breeding season, and at the same time to try to raise young for myself by the artificial fertilization of eggs taken from the ovaries. I had complete suc-

cess with the second method from the first, and succeeded in raising countless millions of young oysters, and in tracing them through all their stages of development up to the time when they had acquired all the characteristics which Salensky, Lacaze Duthiers, Möbius and others have figured and described in the young European oyster at the time it leaves its parent. I also made careful examination of the gills and mantles of more than a thousand oysters, but never found a single fertilized egg or embryo inside the mantle-cavity of an adult, although I found females with the ovaries full of ripe eggs, others with the ovaries half empty, others with them almost entirely empty, and others at all the intermediate stages, and I therefore feel sure that my examinations were made upon spawning oysters.

While this evidence is for only one season and one bed, I think that until it is shown to be exceptional, we must conclude that there is an important difference in the breeding habits of American and European oysters, and that the eggs of the American oyster are fertilized outside the body of the parent; that during the period which the European oyster passes inside the mantle-cavity of the parent, the young American oyster swims at large in the open ocean.

The more important points in the development of the oyster are:

1. The oyster is practically unisexual, since at the breeding season each individual contains either eggs or spermatozoa exclusively.

2. Segmentation takes place very rapidly and follows substantially the course described for other Lamellibranchs by Lovén and Flemming.

3. Segmentation is completed in about two hours, and gives rise to a gastrula, with ectoderm, endoderm, digestive cavity and blastopore, and a circlet of cilia or velum. At this stage of development the embryos crowd to the surface of the water and form a dense layer less than a quarter of an inch thick.

4. The blastopore closes up; the endoderm separates entirely from the ectoderm, and the two valves of the shell are formed, separate from each other, at the edges of the furrow formed by the closure of the blastopore.

5. The digestive cavity enlarges, and becomes ciliated, and the mouth pushes in as an invagination of the ectoderm at a point directly opposite that which the blastopore had occupied. The anus makes its appearance close to the mouth.

6. The embryos scatter to various depths, and swim by the action of the cilia of the velum. The shells grow down over the digestive tract and velum, and the embryo assumes a form so similar to various marine lamellibranch embryos which are

captured by the dip net at the surface of the ocean that it is not possible to identify them as oysters without tracing them from the egg. The oldest ones which I succeeded in raising in aquaria were almost exactly like the embryos of Cardium, figured by Lovén.

7. The ovaries of oysters less than 1¼ inches in length, and probably not more than one year old, were fertilized with semen from males of the same size, and developed normally.

An illustrated paper on the embryology of the oyster, with a detailed account of my observations, will be published, shortly, in the Report of the Maryland Fish Commission for 1879.

Baltimore, Nov. 5, 1879.

ART. LII.—*Origin of the Lœss*; by G. C. BROADHEAD.

WHAT facts Baron von Richthofen may have observed in Eastern Asia tending to form his opinion of the origin of the lœss I have not had the opportunity to examine; but from careful observations of the lœss in many places along and adjacent to the Missouri and Mississippi rivers, I cannot refer these deposits to æolian or wind-drift agency. Professor Hilgard, in his article in this Journal for August, conveys to us some interesting and correct testimony.

That the lœss is stratified in many places I can bear testimony; a notable example may be seen in the bluffs at St. Charles, Mo., near the railroad depot, where it shows finely laminated deposits, made up of planes of differently colored clays and sands, the latter very finely comminuted, showing that at this place the sediment was deposited at different times from very quiet waters. The beds of sand also sometimes appear evidently as if deposited from water. Calcareous concretions are quite characteristic of the lœss. They are generally of roundish form, but often elongated, and can sometimes be traced for several hundred feet horizontally, forming beds from a few inches to more than a foot in thickness. The concretions are either united to each other or often separated.

Land snails are occasionally found. Some of the sands are ferruginous, and pipe-stem forms of iron sand are occasionally found, with also hollow root-like forms of calcareous matter. The cohesive strength of the particles tends to preserve the mass in a vertical position for a long time, even at sixty to seventy feet height. When not quite as cohesive, time will wear off the rougher points, and produce rounded mammillated

hills covered with a thin soil, and sloping at about an angle of 50°; for example, the "Mamelles" below St. Charles, and the hills at Glasgow and St. Joseph. Our richest upland soils near the Missouri river are due to a subsoil of lœss.

Lastly, the æolian hypothesis is untenable when referred to the lœss of the valleys, hillsides, and hills adjacent to the Missouri and Mississippi rivers; for, although often of a depth from twenty to two hundred feet, it cannot be clearly traced far back from these rivers, and I believe in Missouri not farther than fifteen miles from them. It must therefore have been a sediment in the quiet waters when the rivers were blocked up below by ice; when the barrier melted away a channel was worn through the silt, leaving these finely comminuted clays on the neighboring hills as we now find them.

The waters of the Missouri river are full of very minute particles held in suspension. Its waters appear to be whirling continually, the channel is daily changing, sands are deposited on the bars, and fine silt at quiet eddies or in the mouths of the small tributaries, and the latter closely resembles the lœss of the neighboring hills. The most if not all of these clays may have originated from the Tertiary and Cretaceous beds of the Upper Missouri.

ART. LIII.—*Observations on the planets Hersilia and Dido;* by Professor C. H. F. PETERS. (From a letter to the Editors, dated Litchfield Observatory of Hamilton College, Clinton, N. Y., November 8, 1879.)

IN the month of October, two planets were added by me to the group between Mars and Jupiter. I take pleasure in communicating the following observations on their positions. The dates of discovery were respectively Oct. 13 and Oct. 22.

(206) *Hersilia.*

1879.	Ham. Coll. m. t.	App. α.	App. δ.	No. of comp.
Oct. 13.	14^h 35^m 52^s	1^h 0^m $36^s\cdot63$	$+1°$ $24'$ $52''\cdot2$	15
Oct. 14.	10 43 25	0 59 56·51	+ 1 19 54·1	10
Oct. 16.	9 51 24	0 58 23·52	+ 1 9 10·6	9
Oct. 20.	9 46 52	0 55 17·26	+ 0 48 11·1	10

(209) *Dido.*

1879.	Ham. Coll. m. t.	App. α.	App. δ.	No. of comp.
Oct. 22.	14^h —^{m} —^{s}	1^h 23^m 49^s	$+13°$ 23·1	—
Oct. 25.	11 12 36	1 21 32·94	+13 14 27·4	10
Oct. 26.	10 49 55	1 20 47·08	+13 11 20·4	10
Nov. 7.	12 1 6	1 12 12·93	+12 33 1·1	4

The magnitude of Hersilia was 11th; that of Dido about 12th.

ART. LIV.—*On Triple Objectives with complete Color Correction;* by CHARLES S. HASTINGS.

THE prime defect in the large refractors of the present day is the secondary spectrum. This, arising from the irrationality in the spectra produced by the crown and flint glass, hardly noticeable in small apertures, detrimental in telescopes of medium power, is positively obnoxious in the large instruments and will speedily put an end to farther increase in dimensions. On this account there have been many efforts to produce two kinds of glass differing sufficiently in dispersive power, which would still yield mutually rational spectra. As far as I know we are now no nearer success in this direction than when Brewster investigated the subject fifty years ago.

Can we secure the same end by increasing the number of glasses in the objective? Theoretically, since a new disposable constant for color change is introduced with each lens in the system, the answer is evidently affirmative; but if we limit ourselves by the condition that the construction shall be practicable, i. e., that there shall not be too many lenses and the curvatures shall be moderate, the conclusion is not so ready. On entering the discussion we will assume three as the limiting number of lenses and $\frac{1}{18}$ the focal length as the minimum radius of curvature.

The formula for the focal length F of three thin lenses in contact is, if we set $\varphi=\frac{1}{\mathrm{F}}$:

$$\varphi=(n'-1)\left(\frac{1}{r_1}+\frac{1}{r_2}\right)+(n''-1)\left(\frac{1}{r_3}+\frac{1}{r_4}\right)+(n'''-1)\left(\frac{1}{r_5}+\frac{1}{r_6}\right),$$

where n', n'', n''' are the indices of refraction for the three materials used, and r_1, r_2, ... r_6, are the radii of curvature for the six surfaces successively. We may write this more concisely for our end, as follows:

$$\varphi=(n'-1)\mathrm{A}+(n''-1)\mathrm{B}+(n'''-1)\mathrm{C},$$

calling A, B and C the *curvature sums* of the first, second and third lens respectively.

The problem then, succinctly stated, is to find values of A, B and C, no one of which shall be more than thirty when $\varphi=1$ and which shall make φ independent of the wave length of light transmitted.

If n can be expressed as a function of any variable x of the form:

$$n=A+Bf_0(x)+\Gamma f_1(x)$$

the problem has its mathematical expression in the equations:

$$\varphi_\lambda=(n_\lambda{}'-1)\mathrm{A}+(n_\lambda{}''-1)\mathrm{B}+(n_\lambda{}'''-1)\mathrm{C}=1$$

$$\frac{d\varphi}{dx}=(B'f_0'(x)+\Gamma'f_1'(x))\mathrm{A}+(B''f_0'(x)+\Gamma''f_1'(x))\mathrm{B}+(B'''f_0'(x)+\Gamma'''f_1'(x))\mathrm{C}=0;$$

but since the latter must hold true for all values of the variable x the final conditions for perfect color correction are:

$$\left.\begin{array}{r}(n_\lambda{}'-1)\mathrm{A}+(n_\lambda{}''-1)\mathrm{B}+(n_\lambda{}'''-1)\mathrm{C}=1\\ B'\mathrm{A}+B''\mathrm{B}+B'''\mathrm{C}=0\\ \Gamma'\mathrm{A}+\Gamma''\mathrm{C}+\Gamma'''\mathrm{C}=0\end{array}\right\} \qquad (2)$$

the only practical limitation being that neither A, B or C surpass thirty as a maximum.

As to the choice of the variable x, the most natural suggestion is the wave length of light, using the first three terms of Cauchy's well-known formula as an expression for n; but there are two objections to such a course, the first and most important being that three terms of this series will not express the values within the necessary limits of accuracy, and the other lies in the great labor requisite to compute the constants. I have, therefore, chosen to take the value of n for some one material as a standard and compute by the method of least squares the values for other materials as functions of this. The standard selected is Feil's Crown Glass, No. 1219, which I have studied and described, with four other kinds, on page 273 vol. xv, of this Journal. The reason determining the choice is the greater accuracy of our knowledge of its constants over that of any other light glass. The form of the function is a trinomial of the second degree, thus:

$$\mathrm{N}=A+Bn+\Gamma n^2 \qquad (3)$$

Doubtless by not restricting it to the first and second powers of n a formula might be shaped which would make the differences between the observed and calculated values less, but as that could be attained only at the expense of much greater labor in determining the various values of the constants, and moreover, as the errors of observation are generally greater than those of the formula, it seems unadvisable to modify it.

In this discussion I have included all the different varieties of glass the optical constants of which I have been able to find given with the requisite accuracy. Unfortunately there are but few. Besides the five which I have determined and are cited above, viz:

Feil's Crown 1219, ... α
" Flint 1237, ... β
" Flint 1241, ... γ
—— Crown A, ... δ
—— Flint B, ... ε

are included the seven of Fraunhofer,* viz:

Crown 13,	ζ
Crown 9,	η
Crown M,	ϑ
Flint 13,	ν
Flint 3,	κ
Flint 30,	λ
Flint 23,	μ

six of Van der Willigen† (one closely resembles my A above, while two others are almost exactly alike), viz:

Crown, Merz No. III,	ν
Crown, Merz No. IV,	ξ
Flint, Steinheil No. II,	o
Flint, Merz No. V,	π
Flint, Hoffmann No. I,	ρ
Flint, Merz. No II,	σ

and finally one of Ditscheiner,‡

Flint, ——,	τ

There are further measurements of 18 different prisms by Dutiron,§ but so inaccurate as to be worthless for our purpose.

In the order in which the glasses are named are entered in table I, the values of the constants for (3).

TABLE I.

	A.	*B.*	*Γ.*
α	+ 0·	+ 1·	+ 0·
β	22·3186075	−29·1759937	10·2399102
γ	14·0097123	−17·9513549	6·4320057
δ	·5679958	+ ·2172063	·2681091
ϵ	21·026827	−27·430617	9·645678
ζ	·5749543	+ ·2333290	·259890
η	·9025943	− ·2110704	·411148
ϑ	5·2924649	− 6·1318968	2·4193199
ι	19·6074744	−25·7440377	9·1597811
κ	20·7768050	−27·0625275	9·5093547
λ	24·6152640	−32·2820439	11·2916241
μ	25·4950932	−33·4611946	11·688423
ν	2·250818	− 1·973145	0·983738
ξ	2·737385	− 2·679993	1·241673
o	19·541685	−25·438209	8·976709
π	27·444400	−36·035067	12·537277
ρ	43·623628	−57·822556	19·899438
σ	69·141334	−91·827575	31·313410
τ	19·960275	−26·041640	9·196286

* Schumacher's Astronomische Abhandlung für 1823.

† Archives du Musée Teyler.

‡ Sitzungsberichete der k. k Akad. d. Wissenschaften in Wien. Oct., 1864.

§ Comptes Rendus, xxix, pp. 632–636. Poggend. Annal., lxxix, pp. 335–336. Annales de Chimie, xxviii, pp. 176–210. These incredible values, which are extensively quoted in prominent text books on optics, have given me a deal of trouble, used as they are in several places to discuss the defects and possible improvement of the double objective. Only by the merest chance I found on the last leaf of the Annales de Chimie, xxviii, pp. 501, 502, a set of corrections to *all* the values. These new values are less fantastic, but still the errors are large and even indicated anomalous dispersion is not wanting.

If we tabulate the differences between the observed values and those derived by substitution in the formula, we have the following expressed in units of the sixth place:

TABLE II.

$n - N$.

	A	B	C	D	λ 5614	E	F	λ 4548	G	h	H
α	0	0	0	0	0	0	0	0	0	0	0
β	+26	− 4	−12	−31	− 6	+ 3	+23	+ 4	+12	− 4	−10
γ	+24	−10	−10	−21	− 4	+ 6	+19	+ 4	+ 4	− 1	− 7
δ	− 9	− 0	+ 2	− 1	+15	+15	−14	—	−20	0	+12
ε	+ 8	− 8	− 3	−10	+ 4	+13	+ 5	—	−10	− 9	+12
ζ	—	+ 2	+ 4	− 1	—	+ 4	−11	—	− 4	—	+ 3
η	—	−15	+ 4	+16	—	− 3	+17	—	−34	—	+16
ϑ	—	+ 4	+ 8	−25	—	+10	+ 6	—	− 2	—	− 1
ι	—	− 2	− 7	−21	—	+36	+15	—	−24	—	+ 2
κ	—	−42	+29	+35	—	−11	−20	—	+ 5	—	+ 2
λ	—	− 1	+45	−27	—	+ 7	− 7	—	+19	—	−36
μ	—	+19	+10	−34	—	−30	+24	—	+30	—	−19
ν	+23	+19	−22	−42	—	+14	+20	—	+13	+19	
ξ	+21	− 3	−16	−15	—	+15	+11	—	−10	+22	
ο	+38	−27	−13	−25	—	+ 2	+28	—	+15	−19	
π	+54	−16	−37	−34	—	− 9	+28	—	+29	+17	
ρ	+40	−19	−30	−19	—	+11	+25	—	+ 4	−11	
σ	−60	−47	−26	+25	—	+119	+116	—	−32	−92	
τ		− 8	+26	−10	−34	− 0	+43	—	+ 8	−26	

The systematic distribution of the differences in the first group shows, not only the short-coming of the formula, but also that the extreme accuracy, indicated by the probable errors attached to the indices, is not imaginary.

The accuracy of the second group is also great but much inferior to the first. Occasional abrupt changes as in that of ιD to ιE in table II can only arise from erroneous values in the indices. Here we recognize at once that n_E must be about thirty too great.

The indices of the following groups are only given to five places of decimals and are evidently made with much less care than the others.

By taking from table I the constants for any three glasses and substituting them in formulas (2), we obtain values of A, B and C, which would give complete color correction, but in general the values would not be all below thirty, the limiting maximum. Of those, however, which satisfy this condition, I select four cases, confining myself to these four, not because it exhausts all the serviceable combinations or even gives the smallest values for the curvature sums, but because it introduces eight out of the nineteen glasses which are most useful. They are:

Case I.	α	β	ι
" II.	ν	π	o
" III.	ν	π	τ
" IV.	ξ	π	o

giving values for the curvature sums:

	A.	B.	C.
I.	3·47026	7·20807	− 8·35472
II.	9·47513	14·28004	−21·23665
III.	7·58585	11·57425	−16·59076
IV.	11·67459	18·10299	−27·22301.

Substituting these values in the general formula (1) we derive for F the following, the first column giving the Fraunhofer ray for which the focal length is computed:

TABLE III.

	I.	II.	III.	IV.
A	———	1·00002	———	1·00000
B	1·00000	·99949	·99989	·99968
C	·99999	1·00043	1·00102	1·00053
D	·99999	1·00026	1·00052	1·00005
E	1·00024	·99992	·99942	·99993
F	·99999	·99988	·99951	·99999
G	·99999	1·00002	1·00030	1·00000

To exhibit more distinctly the improvement in this form over the double objective, I arrange the differences in the above values between each and the true focal length of that system in a table, supplementing it with a sixth column in which are entered the corresponding differences for a double objective of glasses α and β with its best color correction, and having a focal length of unity.

TABLE IV.

	I.	II.	III.	IV.	V.
A	−	+ 2	−	− 3	+135
B	+ 1	−53	−22	−35	+ 66
C	0	+41	+91	+50	+ 41
D	0	+28	+41	+ 2	+ 0
E	+25	−10	−67	−10	+ 13
F	0	−14	−60	− 4	+ 73
G	0	+ 2	+21	− 3	+287

The large difference in F_E is owing to an erroneous value of n_E in Fraunhofer's Flint 13.

The greater differences in the other cases are to be attributed to inaccurate measurements of the optical constants, inaccuracies which are most marked in Ditscheiner's determinations. It may be noted that only in the first two groups are the indices given to six places of decimals, and whatever the errors may be they are multiplied by large factors in all but the first case. That these differences do not represent any outstanding color we may be sure from their non-systematic character.

The problem is then solved generally and shown to be quite practicable in the case of a number of known varieties of glass.

Of course in its practical application this process should be used to yield a first approximation only, since the thicknesses and distances of the lenses are neglected; but having this there is no difficulty, other than the laborious character of the computations involved, in determining by successive approximations the values of all the radii requisite to secure complete color correction and at the same time eliminate spherical aberration. As in the case of a double objective, after satisfying the conditions of given focal length, of color correction, and elimination of spherical aberration, we have one arbitrary condition to impose, so in a triple objective we have two arbitrary conditions to impose. In my opinion, were we using materials that required large curvature sums, it would be advantageous to utilize these two conditions in making two of the lenses respectively biconvex and biconcave, thus rendering the necessary thickness of the materials a minimum.

These results are directly opposed to those of a recent writer in this Journal.* But his conclusions arise from erroneous calculation. Not only does his interpretation of his equation (12) imply the manifest absurdity that in a system of infinitely thin lenses in contact its properties are determined by the order of the lenses, but the interpretation is impossible. True A_2 should have an opposite sign to A_1+A_3, but that asserts nothing as to likeness of the latter symbols in sign. Thus n in equation (16) may be negative and consequently his subsequent reasoning is fallacious, for in that case n does not have to be infinite to cause equation (27) to vanish. I may add that the origin of the confusion is in making the ratio $\frac{D}{E}$ in equation (9) constant; it may be, and if course should be, indeterminate.

Professor Harkness has made another mistake, founded upon inadequate experiment, which has so important a bearing on the theory of the double objective that it should not be allowed to pass uncorrected. His statement (p. 191) concerning the condition for color correction, is substantially correct, though, in my opinion, it is not self-evident but requires proof. This proof I shall supply in a forthcoming number of the American Journal of Mathematics. His experiment, however, (p. 193) directly contravenes this principle, for he finds that the focal plane does not correspond to the minimum focal distance, but to something greater. The source of error is the introduction of a variable element in the system, namely, the eye, which would adjust itself differently in observing the star and its spectrum. Had the writer used eye-pieces of successively higher power,

* Professor Harkness, in the September number, pp. 191–193.

thus lessening progressively the power of accommodation of the system, with his prism, he would have seen his points γ_m and γ_n approach until they sensibly coincided; or better still, had he formed his spectrum by a grating (such as perforated card-board) before the objective, instead of by a prism between the ocular and eye, he could not have been misled, since the uncolored image would serve to control the eye.

Finally, the fourth conclusion (p. 196) is strictly true, though we are not to conclude, as would seem from the text, that the detriment due to the secondary spectrum depends either solely upon the aperture or varies inversely as the focal length; for, though the secondary spectrum remains constant in dimension with a given aperture and consequently its angular value decreases inversely as the focus, a stellar image (diffraction disk,) increases directly as the focal length. Hence by increasing this element more of the central portion of the secondary spectrum, i. e. the brighter portion, would be absorbed into the stellar disk. In other words, by doubling the length of the telescope the secondary spectrum becomes much less than half as offensive.

Johns Hopkins University, Sept. 20th, 1879.

ART. LV.—*Geology of Virginia:—Balcony Falls. The Blue Ridge and its geological connections. Some theoretical considerations;* by J. L. CAMPBELL, Washington and Lee University.

AMONG the many localities in the mountains of Virginia that are peculiarly interesting to the geologist, very few offer attractions superior to those found in the great natural section of the Blue Ridge at Balcony Falls, where the James River passes from the Valley to Piedmont Virginia. The canal from Lynchburg to Lexington passes through this mountain gorge, and renders the exposures of the rocky formations easily accessible. Here both the Archæan and the Primordial formations are displayed in their relative positions, and their contact laid bare to inspection. Reference was made to this point in a former paper (July No. of this Journal, pp. 22, 23), by way of illustration. I now propose to discuss some of its interesting features more in detail.

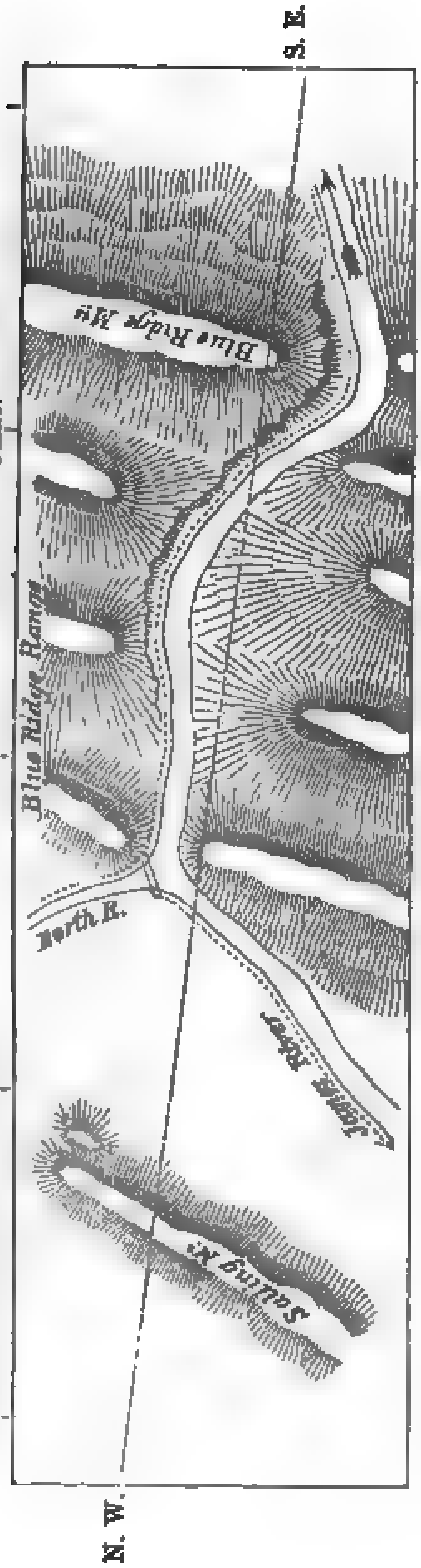
Topography.—The accompanying map and section will serve to throw light upon both the topographical and the geological features of the locality. Leaving out of view a number of irregular foot-ridges on the southeast side, we may regard the

range of mountains here, known as the "Blue Ridge Range," to consist of, (1) the real Blue Ridge on the southeast border—the long water-shed between the valley and Piedmont Counties—between Rockbridge on the northwest and Amherst and Bedford on the southeast. Here and for some miles along its line both ways, this ridge is flanked by Archæan rocks on the southeast and Primordial rocks on the northwest—the latter resting unconformably upon the former. (2) Skirting the northwest side of this leading ridge, and parallel with it, are two well defined lines of broken ridges that have evidently been once continuous, but now consist of short, abruptly terminating mountains, of rounded dome-like hills, and of rugged conical peaks. These all have a frame-work of Primordial sandstones, with the less durable shales of the same period lying along their flanks or filling the depressions between them. Of these lines of ridges the one bordering on the great limestone valley, heretofore described, (see July No.), is by far the most conspicuous, and the most uniform in its physical features. It consists essentially of the durable masses of the Upper Potsdam sandstones, so durable that many parts of it have maintained a height almost equal to that of the main ridge, the average height of which, in this region, somewhat exceeds 2500 feet. The mean bearing of this portion of the range is about N. 35° E.

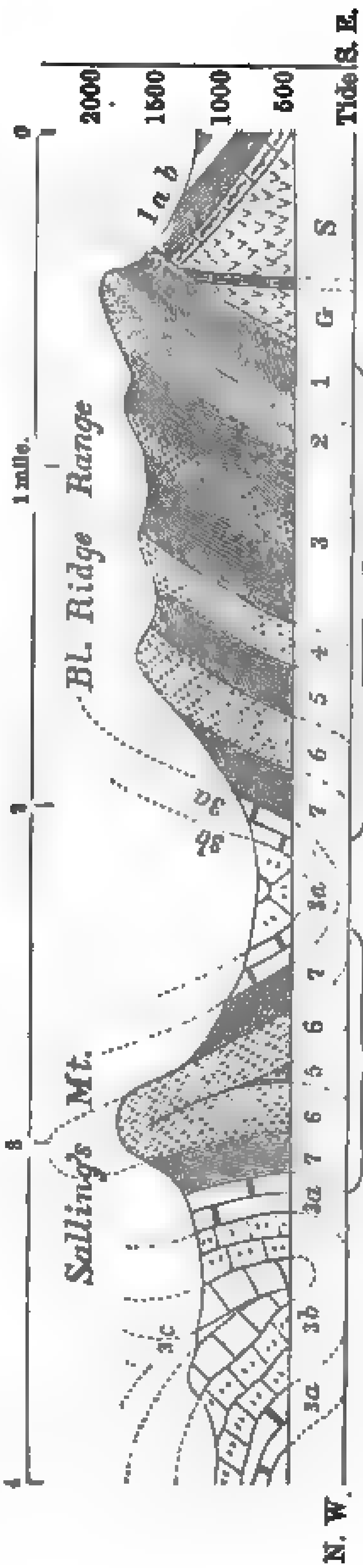
Salling's Mountain, seen on the left of the map, is an outlying ridge of Primordial sandstones and slates, cut off at its northeastern end by the North River, and at its southwestern end by James River. It is separated from the principal chain by a narrow synclinal valley of limestone (Lower Silurian), most of which is concealed from view by an extensive bed of *alluvium*, accumulated by the two rivers that meet here; but accumulated originally in a Y-shaped lake, through which they seem to have flowed at some former period of their history.

The two rivers above mentioned, traverse the little valley obliquely, and meet at a very obtuse angle just where their waters, as one united stream, enter the deep gorge or cañon by which they pass through the mountain range. Just below their junction are mills for grinding hydraulic lime burnt from the ledges that crop out a little higher up the James River. "Balcony Falls" is the name given to a succession of "rapids," beginning about half-a-mile below the Cement Mills, and continuing to the southeast limit of the gorge. The river here is 700 feet above tide level.

Geology.—The foregoing outline of the topography of the region will enable the reader to understand more clearly its geological peculiarities, and to interpret more readily than he otherwise could, the ideal section accompanying the map.



MAP OF CAÑON AT BALCONY FALLS, VIRGINIA.



SECTION AT BALCONY FALLS, JAMES RIVER.

Conceive a vertical plane with its edge resting on a line represented by the broken line of the map, marked "S.E.," and "N.W.," and having a height of 1500 feet above the bed of the river. Then imagine all the outcropping faces and edges of all the eroded rocks of the gorge, and all that the plane itself would cut (including those of Salling's Mountain), to be pictured on the plane, and you will have a mental conception of what the section is designed to represent.

The student of geology will find here a somewhat intricate, but a very interesting problem for solution. By a series of careful observations along the canal and bed of the river, and also by the turnpike that crosses the mountain near the canal, very satisfactory conclusions may be reached. In the gorge we have the rocks of two distinct eras so meeting as to enable us to study not only their composition and structure, but also their relative positions, and some of the metamorphic influences they have exerted upon one another. These two eras are, (1) the Archæan, represented on the accompanying section by the rocks on the right marked G, S, and 1 *a*, *b*; (2) a portion of the Lower Silurian covering the remainder of the section.

Let us begin at the base of the Archæan. Here we find two masses, or a sort of double mass, marked G. and S.—the former a mass of Granulite, and the latter of Syenite. These are usually regarded as igneous, or perhaps with more propriety, aqueo-igneous rocks. They underlie the stratified rocks of this era; but, considered as solid rocky masses, they are probably of more recent date than any other rocks represented on the section—having been thrust upward beneath the over-lying stratified beds in a plastic (semi-fused) condition, and subsequently hardened into their present condition.

G. is "granulite"*—a granitoid rock, eruptive in its origin. It is composed of granular quartz mixed with feldspar, both white and pale flesh-colored; and has numerous crystals of garnet, and occasional crystals and blotches of epidote disseminated through it, giving it a spotted appearance. This is about 100 feet wide at the base, and seems to be separated from the larger mass of syenite (S.) by a crushed and greatly metamorphosed bed of gneissoid rock, in which distinct traces of the original bedding can be seen. The syenite is well exposed from a short distance below the limit of the granulite, as far down the canal as to lock No. 15. It also forms a rugged bed for the river in this part of its course, and rises to the height of several hundred feet beneath the mountain on the opposite side. Syenite is a granitoid rock composed essentially of quartz, feldspar and hornblende, in varying proportions.

* So classed by Professor Dana, to whom a specimen was submitted.

Besides these constituents we find the mass at Balcony Falls containing, in some places, considerable quantities of epidote, both crystalline and amorphous, giving the rock a green color, and in others numerous crystals of garnet.

The bedded rocks (1, *a*, *b*,) that rest upon the syenite, are very much metamorphosed, are gneissoid in character, and dip toward the southeast. These are succeeded by beds of red and brown slates. Then follows a bed of forty or fifty feet of conglomerate quartzite, bearing some resemblance to the conglomerate sandstones on the opposite side of the ridge, but so unlike in composition, texture, position and thickness as to preclude the idea that they have any historical connection. Over this again we find another bed of slate. These beds all dip towards the southeast, while their upper margins reach beyond the underlying syenite and granulite, and with their edges support the lowest beds of Primordial rocks where they extend high up on the ridges, beyond the limit of the igneous beds. The two series here, and at other points along the ridge, are entirely unconformable. Such are the Archæan rocks.

Starting again on the northwest side of the granulite, let us briefly sketch the remarkable beds that make up the remainder of this massive range. In the Archæan rocks we have just described there are no traces of fossil remains, nor do we find any in the lowest beds of what we call Primordial. If organic remains have ever been imbedded in them here, they have either been obliterated or remain yet to be discovered.

Subdivisions.—On the section illustrating a former article (July No.), the classification of Professor Rogers in his reports was employed, and subdivisions of my own introduced. In a second article (August No.), the classification and notations* of Professor Dana's Manual were introduced. This latter system I shall employ in this paper—introducing subdivisions only in the Primal period, numbered, 1, 2, 3, etc.

The Primal or Potsdam period is often divided into Acadian and Potsdam epochs—2*a* and 2*b*—but as it is very doubtful whether both of these, as they occur farther north, have equivalents here, or if they have, where the horizon between them is to be found, I shall designate the whole period as 2*a*, *b*, and its subdivisions 1, 2, 3, 4, etc. These will correspond with the subdivisions, 1*a*, 1*b*, 1*c*, etc., on my former section. As these were then regarded as only of secondary importance to my main object—the Silurian limestones—a very brief description of them was deemed sufficient; but now they become of prime importance in our discussion, and demand a more full and detailed examination.

* Professor Rogers himself has partially adopted this system in his article on the Geology of Virginia, in Macfarlane's Geol. R. R. Guide.

Without repeating in each case the notation, $2ab$, the several subdivisions will be referred to by the simple numbers, 1, 2, 3, etc. All the beds of this period, with some local and limited exceptions, dip toward the northwest. The slight alternations and variations of dip are confined almost entirely to the thinner beds of sandstone, and the shales contiguous to them (especially in 3), and are limited apparently to points near the margin of the river. Variations in the steepness of dip in the heavy beds of sandstone as they rise toward the crests of the ridges, are, however, common throughout the whole range. The limited irregularities may, with much plausibility, be referred to the undermining action of the river; for there are abundant indications that the water once stood several hundred feet higher in this pass, and in the little valley west of its entrance, than the present height of the river bed.

Subdivision 1 is a bed of conglomerate about fifty feet thick, resting unconformably against the Archæan rocks, and composed of sand, rounded quartz pebbles, fragments and worn crystals of feldspar, with some fragments of epidote, all firmly cemented together, and hardened by the action of heat from the contiguous igneous rocks; followed by several alternations of slates and conglomeritic sandstones, with an aggregate thickness of about 120 feet. This division has been considerably affected by heat throughout. Its position, too, has protected it against the erosive action of the river which has been far less here than it has been among the slates higher up in the series.

Number 2 is a heavy mass of sandstone fully 350 feet thick, and so hard that we may call it "quartzite." It consists of three tolerably distinct beds varying in hardness and color; the lowest being very hard and of a light gray, sometimes pinkish color; the middle one of coarser texture, partly conglomerate and mostly of a greenish gray color; the upper bed is more brittle than either of the other two, and of darker color. These heavy beds of hard sandstone seem to have presented one of the most durable barriers to the passage of the river through the mountain, and doubtless obstructed its flow to such an extent as to keep the water in contact with the higher beds for a period long enough to cause some modifications already mentioned, and others to be noticed hereafter. Before the canal was constructed the steep rugged outcrop of this massive ledge projected considerably over the left margin of the river, and was known as "Balcony Rock"—hence the name of the falls. For some little distance on the west side of this sandstone the river runs nearly with the strike of the strata, exposing in succession the rugged edges of the several beds.

Number 3 consists of two heavy beds of slates separated by a stratum of hard conglomeritic sandstone about sixty feet

thick, and greenish gray color. The slates are of brown, purple and yellow colors, with some thin beds of argillaceous sandstones interstratified. At this point the river has left some marked traces of its former action in eroding the softer, and undermining the harder strata. The most conspicuous irregularity has been caused by the undermining of the interstratified bed of sandstone just mentioned, so as to give it a low, and sometimes waving dip, and to cause a mass of it to slip from its normal position and modify both dip and strike, as seen just above the margin of the canal. This seems to me the only rational way of accounting for the anomalous position of this bed of sandstone at this point, compared with its position at several other points remote from the river. It also explains its want of conformity with the general structure of the whole Primal period, as exhibited all along this part of the Blue Ridge range. These local irregularities are not represented on the section.

It is a little difficult to determine, even approximately, the thickness of this double bed of slates with its enclosed sandstone, but the aggregate must be at least six hundred feet.

Number 4 is not well defined below, since 3 becomes more and more siliceous and blends gradually into it; but the greater part of it is a bed of brownish gray sandstone with a well defined upper surface. It crosses the river at the Cement Mills, and its highest ledge forms the abutment of the dam on the opposite side of the river. Where a deep channel was washed out by a freshet a few years ago, this rock is well exposed on the lower margin of the turnpike, and its upturned edges may be conveniently examined. A considerable exposure of it also crops out above the turnpike between the houses of Messrs. Locker and Campbell, while the corresponding ledge may be seen on the cliff beyond the river. It has a very regularly jointed structure—the cleavage planes being so distinct as to have been mistaken by an unpracticed observer for planes of stratification dipping to the southeast, while the true planes of stratification dip with considerable uniformity and great constancy toward the N.W.

In this and some of the lower beds of sandstone, very faint impressions of fucoids and occasional Scolithus borings are found; but the conglomerate structure is much less prominent here than in the older beds.

Number 5 is made up of numerous thin beds of slate quite different in color and texture from any that we find lower down. They exhibit, where recently exposed in repairing the canal, a great variety of color from nearly pure white kaolin to various shades of yellow, red and brown, and abound in fine scales of mica; but no distinct traces of fossil remains have

been found in them. In the portion near the river their dip varies from 25° to 50°. I estimate their thickness at 180 feet.

Number 6 is, in some respects, the most interesting of all the subdivisions of this Primal group. It is the sandstone that "constitutes the type of this formation." It differs from the beds already described in both its lithological and fossil peculiarities, (see July No., p. 22). It may well be called the "Scolithus sandstone," if we call the primal worms (?) that had their millions of habitations in this rock the "*Scolithus linearis.*"

Its entire thickness (including some quite brittle beds that underlie and overlie the more massive portion), is about 340 feet. The dip at the base of the ridge, where the two rivers meet at the entrance of the gorge, is fully 65°, while it falls gradually to 40° before it reaches the summit—looking as if it might once have been one leg of a grand natural arch, which still stands up with one exposed face forming an almost perpendicular cliff nearly 800 feet in height. There is, however, no point in this portion of the range where I have found it reaching beyond the northwestern line of ridges, of which it generally forms the crest and the greater part of the western slope, as represented on the accompanying section. A part of this sandstone, with the next beds of slate and sandstone below it, has broken loose from the upper outcrop of the ledges on the S.W. side of the river, and slipped down the eastern face of the ridge without any great change of dip. This displaced mass may be seen as a very conspicuous object nearly opposite, though a little below the Cement Mills. It is apparently one of the effects of undermining by high water in the remote past.

Division 7—the upper Potsdam shale—usually extends some distance up the slope of 6, where the normal dip has been preserved, as may be seen at the iron mines a short distance to the N.E., or opposite the Cement quarries, a short distance S.W. of the entrance of the gorge; but just at the entrance it has been eroded by the river and then concealed very much from view by the drift and diluvium of the valley. Its dip increases toward the valley. As nearly as can be determined here, the thickness is fully 600 feet. A sufficient additional description of it may be found in the July number, p. 23. This brings us to the top of the Primordial period.

The next is the Canadian Period (3)—sometimes called, "Middle Cambrian"—and, like the Primordial, belongs to the Lower Silurian Age. It has three epochs, Calciferous (3*a*), Quebec (3*b*) and Chazy (3*c*). The first of these, named from the prominent character of its rocks in New York, might well be called "Hydraulic," in Virginia, as it is generally characterized by the presence of one or more beds of hydraulic limestone. Where our section crosses, this limestone is quarried

from a bed twelve or thirteen feet thick, interstratified with shales and other beds of impure limestone. It dips steeply to the northwest, and again crops out at the base of Salling's Mountain, on the west side of the little valley in which the two rivers meet. Over it lies a part of the Quebec (3*b*), that has escaped the denuding agencies that have operated so extensively over the whole of the Great Valley. It crops out at a number of points along the James River near the cement quarries, and along the base of Salling's Mountain. We have thus a synclinal trough of limestone resting upon the Primordial shales and sandstones, which we find rising again on the west side and forming the mass of the bordering mountain.

In a depression of Salling's Mountain, about half-a-mile to the right of the point cut by the section, and where the turnpike leading from Balcony Falls to the Natural Bridge crosses, we find the shales and thin beds of sandstone of 2*ab*, 7, extending to the top of the ridge, but where the mountain is more elevated, the heavy beds of Scolithus sandstones (2*ab*, 6), form the core of the ridge, all dipping steeply to the southeast: while beyond, the mountain shales of 7 again appear, dipping toward the mountain and apparently beneath the sandstone which elsewhere underlies them. Then as we descend into the valley beyond the mountain we again meet with the limestones and interstratified shales of 3*a* and 3*b*, dipping under 7. These facts lead to the conclusion that the mountain is a closed fold of Primordial strata pushed over toward the northwest, so as to invert all the strata on that side, and place the older above the newer. But on crossing a low ridge half-a-mile from the mountain and parallel with it, the limestones appear again on its western side still dipping southeast, but in their normal order. From an examination of this limestone ridge at different points, the conclusion to which my mind is drawn is, that it consists of a closed synclinal fold, the middle portion of which is the lower part of the Chazy (3*c*), all higher beds having been pressed out and subsequently swept off. This part of the section will be readily understood from simple inspection.

Salling's Mountain will serve as a type of a considerable number of nearly parallel outliers of the main Blue Ridge chain, extending for thirty miles toward the southwest; and consisting of arches of the upper Primordial strata of sandstones and slates, as may be seen on the road leading from Buchanan to the Peaks of Otter, or of closed and inverted folds, a conspicuous example of which may be found in the ridge that separates Buford's Valley in Bedford from the Great Valley in Botetourt County, and is here called Blue Ridge, because it is the geographical watershed between the two counties—not because it is a continuation of that ridge geologically.

Ridges of this class generally lie off from one to several miles from the main range, and seem to have been thrust up beneath the limestones of the Canadian Period, the folds of which were probably much shattered at the time, and subsequently worn or swept away, so as to leave the ridges of more durable sandstone naked for some distance down their steep sides, and flanked along both bases by slates and limestones—the latter often occupying narrow valleys or troughs, like the one above described, or like Buford's Valley in Bedford county, traversed by the A. M. and O. R. R., in going from Lynchburg to Salem.

Theoretical considerations.—1. The Primal strata, as well as all those of later date, given on my two former sections, (July and August Nos.), are of oceanic origin, and the sandstones and conglomerates have evidently been deposited over the bottom of shallow water, and most heavily along the margin of an ancient ocean whose shore-line was the Blue Ridge. The earliest of these beds—those found at the very bottom, and for some distance upward in the series, are composed of the debris of still older rocks that composed the ancient shore land, and that seem to have been metamorphosed before they were worn down as material for the Primordial strata; for in the latter we find fragments of metamorphosed slate, with both fragments and crystals of feldspar, epidote, etc., more or less water-worn, mingled and cemented together, but not otherwise differing from the same material, as we now find it broken down by the weather from the metamorphic rocks of the Archæan land.

2. The irregular, unbedded masses of syenite and granulite that constitute the base of the Blue Ridge, have evidently been erupted since the deposition of the Primordial strata. This is evident from the mode of contact of the two classes of rock—the stratified resting at a high dip against the igneous masses; and also from the influence the heat of the igneous rocks has exerted upon the slates and sandstones overlying them. Again, the higher we ascend in the series the fewer traces we find of the metamorphic changes.

3. As far as we can read the records left upon the Silurian rocks from the Primordial upward, mechanical force seems to be entirely inadequate alone, without the aid of heat from other sources, to produce any very great amount of metamorphism. The extent to which the rocks represented on the several sections I have given—especially on the first—have been subjected to bending and pressure, and consequent friction, ought, according to the mechanical theory of metamorphism, to have made the Great Valley of Virginia one vast mass of metamorphic strata. But no such effect has followed. The limestones have their fossils beautifully preserved. The sandstones have

not been changed to quartzite. The shales are still nothing but fragile shales (with a few exceptions); while the embedded limonite iron ores still retain their water of crystallization. There has been metamorphism, but only limited, not general, except so far as it has been produced through other agencies than heat, or even super-heated water under pressure.

4. Such closed folds as we find in Salling's Mountain, and in many localities among the lower Silurian limestones, seem to have been great wrinkles in the strata, pushed upward (or downward in the case of synclines), and then pressed together by mechanical force acting from a southeasterly direction and in a horizontal plane. This is the only way we can plausibly account for the numerous troughs and arches and folds found along the lines of the several sections we have had under discussion.

5. The flexures and folds of course produced numerous fractures, especially in the limestone beds, and thus prepared the way for the action of the denuding agencies that stripped this great limestone valley of thousands of feet of its original covering. As the pressure was most powerful on the margin nearest the Blue Ridge, so we should expect to find there the flattest folds and the most numerous fractures, and consequently the greatest amount of denudation. Such we find to be the case; for in the first place, we find the higher—the Trenton—limestones from the James to the Potomac nearly all gone from that side of the valley; and in the second place, all the waters in this region flow toward that side, until they approach the base of the mountain near which they continue till they find an outlet by some one of the great streams that carry them through the mountains and finally to the Atlantic Ocean.

Water acting alone could hardly have been the cause of the vast amount, and peculiar kind of denudation we find extending over nearly the whole 6,000 square miles of this limestone valley, unless it had swept over it in one vast torrent sufficiently deep and powerful to have carried whole mountain chains before it. A much more probable hypothesis is that ice as well as water was an important agent in bringing about the great changes of surface that have given this valley its wonderful fertility.

There are indications throughout this whole region of two great flood periods, since the close of Paleozoic time, when the great Appalachian revolution left the vast accumulations of stratified rocks of that remote age in essentially the same relative position they now occupy. But further notice of these must be postponed for the present.

Art. LVI.—*On the Character and Intensity of the Rays emitted by Glowing Platinum*; by E. L. Nichols, Ph.D. (Göttingen.)

In 1860, Kirchhoff* issued his well-known paper on the relation between the capacity of bodies for emitting and for absorbing rays. That essay made a new epoch in the science of Radiation. It offered the first complete proof and the first universal expression of a principle which had existed in the minds of scientists, more or less dimly, since the days of Euler.†

Although the results of that treatise have been repeatedly confirmed by the experience of investigators in Optical Science and in the domain of Radiant Heat, there have been, so far as I know, in spite of the interesting character of Kirchhoff's Function I,‡ no attempts to measure its values.

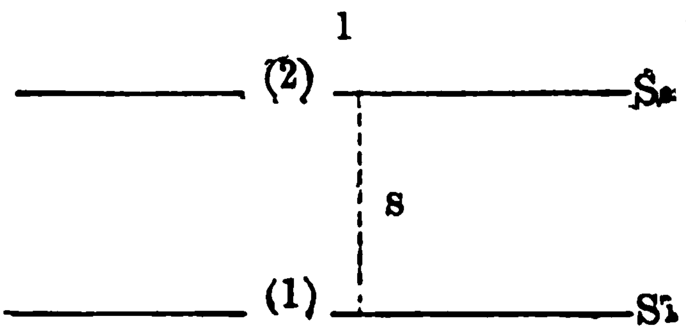
* Kirchhoff, Poggendorff's Annalen, cix; also, "Untersuchungen über das Sonnenspectrum—Anhang."

† For earlier attempts to express what is now known as Kirchhoff's Law, see Euler, Opuscula Varii Argumenti, Berol. 1746 (Nova Theoria Lucis et Colorum, Cap. V). Pierre Prevost, Physische-mechanische Untersuchungen über die Wärme, Halle, 1798. Ångstrom, Poggendorff's Annalen, xciv. Balfour Stewart, Proceedings of the Royal Society of Edinburgh, 1857–58.

‡ In the above-mentioned treatise Kirchhoff gives for I the following formula:

$$e = \mathrm{I}\frac{w_1 w_2}{s^2}$$

where (fig. 1) w_1 and w_2 are the projections of the openings (1) and (2) in the screens S_1 and S_2, upon planes perpendicular to the axis of a pencil of rays, which, going out from the black body C, passes through both of these openings: where further, s is the distance between the two openings, and e the emissive capacity of a black body. A black body according to Kirchhoff, and the same definition applies to the term when used in this paper, is a body which even when of infinitesimal thickness absorbs all the rays falling upon it. The following short extract from Kirchhoff's paper will serve to define clearly what is to be understood by the terms *emissive capacity*, *absorptive capacity*, etc.



"Before a body C (fig. 1) let us suppose two screens S_1 and S_2 to be placed, in which are the openings (1) and (2), of infinitesimal size when compared with the distance between them, and of such shape that each of them may be said to have a center. Suppose the body C to send out a pencil of rays through those two openings. Of this pencil of rays let us consider that portion the wave lengths of which lie between λ and $\lambda + d\lambda$, and let us imagine the same resolved into two components, polarized in the planes a and b. Let the planes a and b pass through the axis of the pencil of rays, and let them be perpendicular to one another. Let, further, $Ed\lambda$ be the intensity of the component a, or, what amounts to the same thing, the increase which the kinetic energy (lebendige Kraft) of the ether behind the screen S_2 suffers in a unit of time by the action of this component. The quantity E is called the *emissive capacity of the body*." (§2 of Kirchhoff's treatise.)

"Suppose the body C to be black. For its emissive capacity, which in general will be denoted by E, we shall substitute e." (§4.)

In the case where for the black body a body of any other kind is substituted, the equation becomes:

I.

It is the purpose of this paper to describe a series of such researches, made in the Physical laboratory of Professor Helmholtz, at Berlin.

The quantity I is (see preceding foot-note) a function of the wave lengths of the ray and the temperature of the radiating body. Its study, therefore, involves the measurement of the intensity of all wave lengths emitted by the source of light in question, at all temperatures for which the rays are of perceptible energy.

The nature of the subject demands different methods of investigation for the study of the visible and of the invisible rays. The measurements to be described in this paper are confined to the visible rays, and the lowest temperature under consideration is that at which bodies begin to glow.

Two platinum wires 100^{mm} long and about $0{\cdot}4^{mm}$ in thickness, served as sources of radiation. Each formed part of a powerful galvanic circuit, in which the current was produced by a Bunsen's battery. The resistance of each circuit could be varied by introducing or withdrawing copper wire, after the principle of the Wheatstone's bridge. One of these bridges served to compensate for the gradual weakening of the battery, so that the glowing platinum could be maintained at a constant temperature. In the other circuit the platinum wire could be given, by means of the bridge, every temperature from a red heat to the melting point.

It being desired to keep the wire in the first circuit at a constant temperature, a delicate mirror galvanometer was adjusted in this circuit, by means of a very weak branch current. This instrument, when carefully compensated with a bar magnet, showed by the motion of a spot of light upon a screen, two and a half meters distant, every change in the intensity of the current and, of course, in the temperature of the wire. The galvanometer, when properly adjusted, was sufficiently delicate to show unmistakably very much smaller changes of temperature than could be detected either by observing with the eye changes of color in the wire, or by studying with any known instrument the changes in the character of the light emitted. Quite as essential to success as the constant temperature of the wires during a single experiment, is the ability to reproduce in the wires, after interruption of the circuits, exactly their former temperatures.

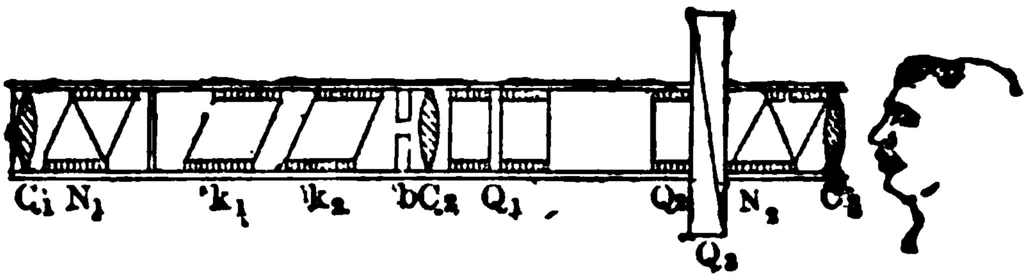
$$\frac{E}{A} = I\frac{w_1 w_2}{s^2}.$$

Here A denotes the ratio of the intensity of rays absorbed by the body to the whole intensity of the rays falling upon it. In other words, A is the *capacity of absorption* of the body.

To lessen the chances of error I used, in addition to the galvanometer, Kitao's* "Leucoscope," an instrument† admirably adapted for showing qualitative differences in the character of heterogeneous rays. I used the original instrument described in Kitao's treatise. The leucoscope is essentially a polarizer, resembling in some respects Soleil's saccharometer.

"N_1 N_2 (fig. 2) are two Nicol's prisms, k_1 k_2 denote two

2.



exactly similar rhombohedra of calcareous spar, *g* is a plate of mica, thin enough to show colors of the first order, *b* is a slit, the width of which can be altered at pleasure by means of an appropriate adjustment. Q_1 Q_2 are two quartz plates, cut perpendicularly to the optical axis. Q_3 denotes two wedge-shaped quartz plates also cut perpendicularly to the axis. These plates turn the plane of polarization in the opposite direction from Q_1 Q_2. C_1 C_2 C_3 are lenses, the focal distances of which are such as to give a sharp enlarged image of the slit, and of distant objects, the images of which are cast upon the slit by the lens C_1. These parts are set in a tube, blackened on the inside to exclude all foreign and useless light." Light entering the instrument is polarized at N_1, split into two rays by the rhombohedra, so as to form a double image of the slit *b*. As the observer rotates the ocular Nicol N_2, the action of the mica lamina and of the quartz plates gives to the two halves of the double image different tints, alternating between red and green. Whatever be the character of the ray, a thickness of quartz can be found such that at four positions of the ocular Nicol, distant 90° from one another, the two halves assume the same neutral tint. Kitao calls this the point of maximum paleness. This thickness of the quartz plates varies with the composition of the ray, and a means is thus afforded of detecting minute qualitative differences in its light. When the experimenter, having adjusted the instrument for a particular kind of heterogeneous light, turns—without changing the quartz plate—to the observation of rays which differ from those of the first source, he finds that the position of the ocular Nicol corresponding to the maximum of paleness differs for each new kind of light.

A series of experiments were made to test the adaptability

* Diro Kitao, "Zur Farbenlehre, Inaugural-dissertation, Göttingen, 1878.

† For a full description of this interesting apparatus, which being a new invention is not so widely known as it deserves to be, I must refer for lack of space to Kitao's paper.

:he leucoscope to this purpose. Its sensitiveness is best wn by the final test, the comparison of two parts of the same ·oleum flame. These portions, a cooler and a warmer, were similar in color that with the unaided eye no difference ld be detected. The mean of twenty observations with the :oscope gave for the position of the ocular Nicol,

TABLE I.

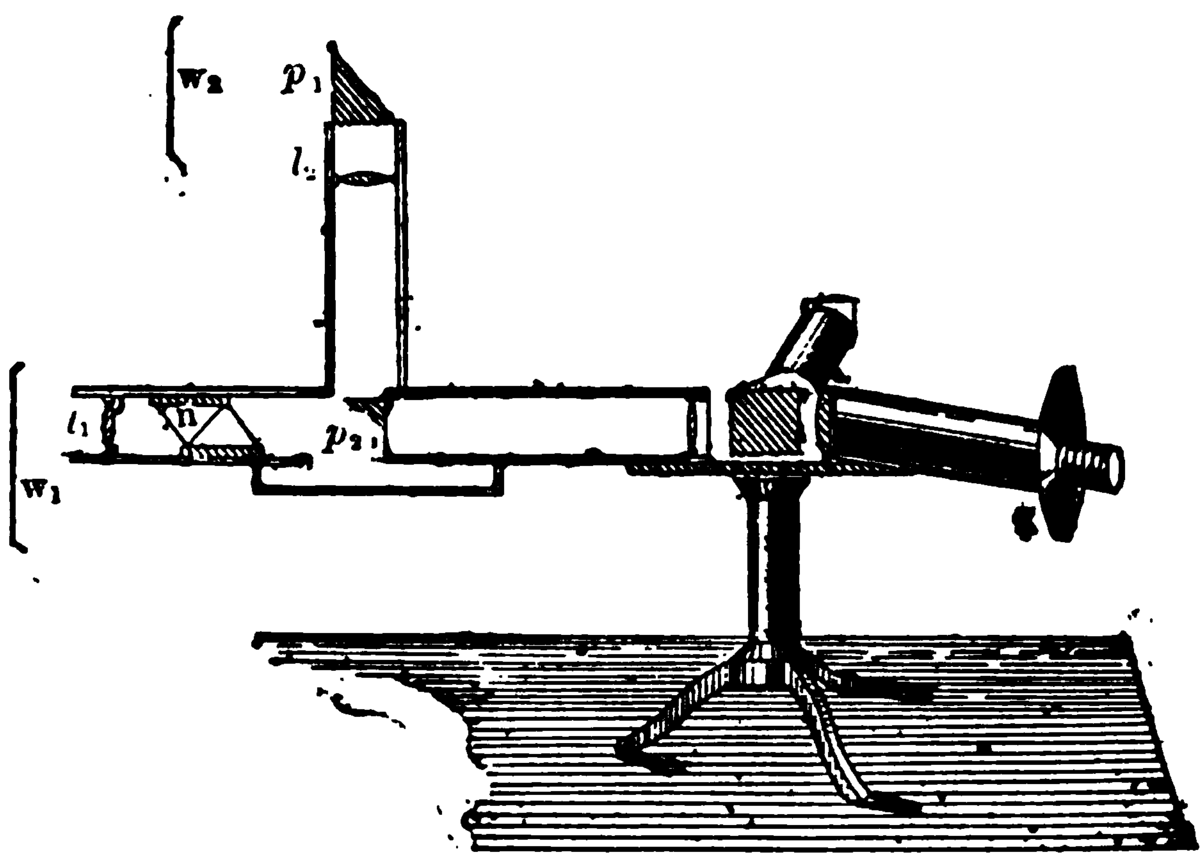
For the upper part of the flame	64°	4′
For the lower part of the flame	62	16
Difference	1	48

m this it is evident that differences in the quality of rays onger visible to the eye, can be detected with the leucoscope. 'he two platinum wires having been given the desired tem·ıture by a proper adjustment of the Wheatstone's bridges, change in the character of the light could be at once noticed neans of the galvanometer and leucoscope; and it was easy letermine whether, during the twelve to fifteen minutes rse of a single experiment, any important change was caused the loss of energy in the battery. Experience showed that loss of intensity during a single experiment was so small : it could be left out of account.

II.

'he experiments to be described in this paper were simply :tro-photometric comparisons of the light emitted by the two

3.



s. One of the wires was given successively various temtures between 1200° and 1900° of the platinum thermom-* and all visible wave lengths radiated by this wire were pared with the corresponding rays from the other.

* See page 451.

The spectro-photometer used agreed with the already existing instruments in permitting the direct comparison of similar rays. The two horizontally dispersed spectra were vertically one above the other, so that in both equal wave lengths lay in the same line. It differed, however, in various particulars from the spectro-photometers of Vierordt, Glan, and Hüfner. The slit is bisected by the finely ground edge of the small rectangular prism p_2 (fig. 3). The lens l_1 throws an image of the glowing platinum wire w_1 upon the lower half of the slit. The rays of the other wire, w_2, after total reflection in the prism p_1, passage through the convex lens l_2 and a second total reflection in the small prism p_2, form a similar image upon the upper half of the slit. This pencil of rays is not polarized, whereas the rays from w_1 are polarized by passing the Nicol's prism n. Both sets of rays after passing the collimator tube, the large dispersing prism, the telescope and the ocular Nicol, reach the eye in form of two spectra, lying side by side. When the two sources of light are of equal intensity, and the planes of polarization of the two Nicols are parallel, the rays from w_1 suffer less loss in transmission to the eye, and give in consequence the brightest spectrum. Its intensity for all positions of the Nicol is given by the formula

$$I = \cos^2 \alpha, \qquad (3)$$

where α is the angle between the planes of polarization of the Nicols. The measurements were made by turning the ocular Nicol until the rays in the two spectra were equally bright. My experience in the use of the instrument was but a repetition of that of former observers. The varying delicacy of the eye at different times and for different colors, especially in the study of the extreme red and violet rays, influenced greatly the accuracy of the measurements.

An ordinary micrometric scale, such as are generally attached to spectroscopes, was used to mark the various spectral regions to be studied, and the position of the principal Fraunhofer's lines upon this scale having been carefully noted, it was made fast, and not moved again during the whole course of the investigations. These positions, according to the mean values of sixteen readings for each line, were as follows:

TABLE II.

Lines.	Scale-divisions.	Lines.	Scale-divisions.
A	7·35	b	12·84
B	8·05	F	14·63
C	8·74	G	19·03
D	9·95	H	23·28
E	12·37	....	....

III.

The accurate determination of the temperature of a glowing platinum wire, presents serious difficulties. Repeated attempts

to use Matthiesen's formula for the change of electric resistance with the temperature, only showed the impracticability of this method.

Only the middle portion of a glowing wire can be said to be of equal temperature throughout. If we measure the resistance of the wire when hot and cold (in itself no easy task), the change corresponds to a difference of temperature which gives, so to speak, the *mean* temperature of the whole wire; a quantity which must then be used, together with h and k (inner and outer conductivity of the metal), and with the dimensions of the wire, in the calculation of the distribution of temperature throughout its various parts. Aside from the difficulty of finding an applicable expression for this distribution, our imperfect knowledge of the quantities h and k for platinum, as functions of the temperature, would render the calculation of doubtful value.

The method finally adopted was to measure directly the expansion of the wire. By observing it from end to end with the leucoscope, while glowing, it was found that for a portion in the middle, about 60^{mm} long, the light radiated was, for the whole distance, of like character. This then was the greatest admissible length of the piece to be measured. In reality the section chosen was much shorter (45^{mm}), so that certainly within its limits, only imperceptible differences of temperature occurred.

A degree of the platinum thermometer may be defined as that change of temperature which causes in a platinum wire a linear variation of $1:1{\cdot}00000866$. Then for a wire 45^{mm} long, one degree corresponds to an expansion of about $0{\cdot}0004^{mm}$, and it was desirable in determining the temperature to be able to measure its length to within a few ten-thousandths of a millimeter. For this purpose I used a finely constructed Helmholtz's Opthalmometer; the following description of which is taken from Helmholtz's "Handbuch der physiologischen Optik," (p. 8). "The opthalmometer is essentially a telescope arranged for short distances, before the objective lens of which two glass plates stand side by side, so that one-half of the lens looks through the one, the other half through the other plate. When both plates are in a plane perpendicular to the axis of the telescope, there appears a single image of the object in view. Let them be turned a little, however, toward opposite sides, and the single image divides into two halves of a double image; the distance between which increases with the angle between the plates. This distance can also be calculated from the angle which the plates make with the axis of the telescope."

If a ray pass obliquely through a glass plate its displacement S will be, (fig. 4),

$$S = \frac{\sigma \sin (i - r)}{\cos r} \qquad (4)$$

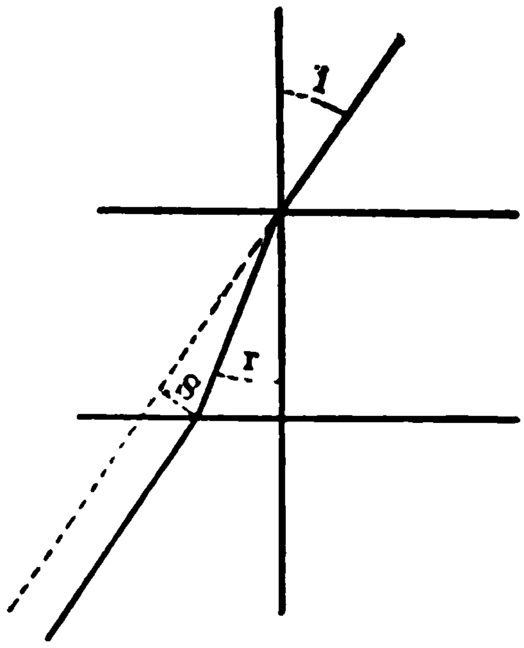
where σ denotes the thickness of the plates,
i denotes the angle of incidence,
r denotes the angle of refraction.
Eliminating r the equation becomes,

$$S\sqrt{1 - \frac{\sin^2 i}{n^2}} = \sigma \sin i\left(\sqrt{1 - \frac{\sin^2 i}{n^2}} - \frac{\cos i}{n}\right) \qquad (5)$$

where n is the index of refraction.

The use of the opthalmometer offers great practical advantages over other micrometric methods, in that the angles corresponding to any given distances are independent of the distance of the object measured, and in that any slight unsteadiness of the object does not affect the accuracy of the determination.

4.



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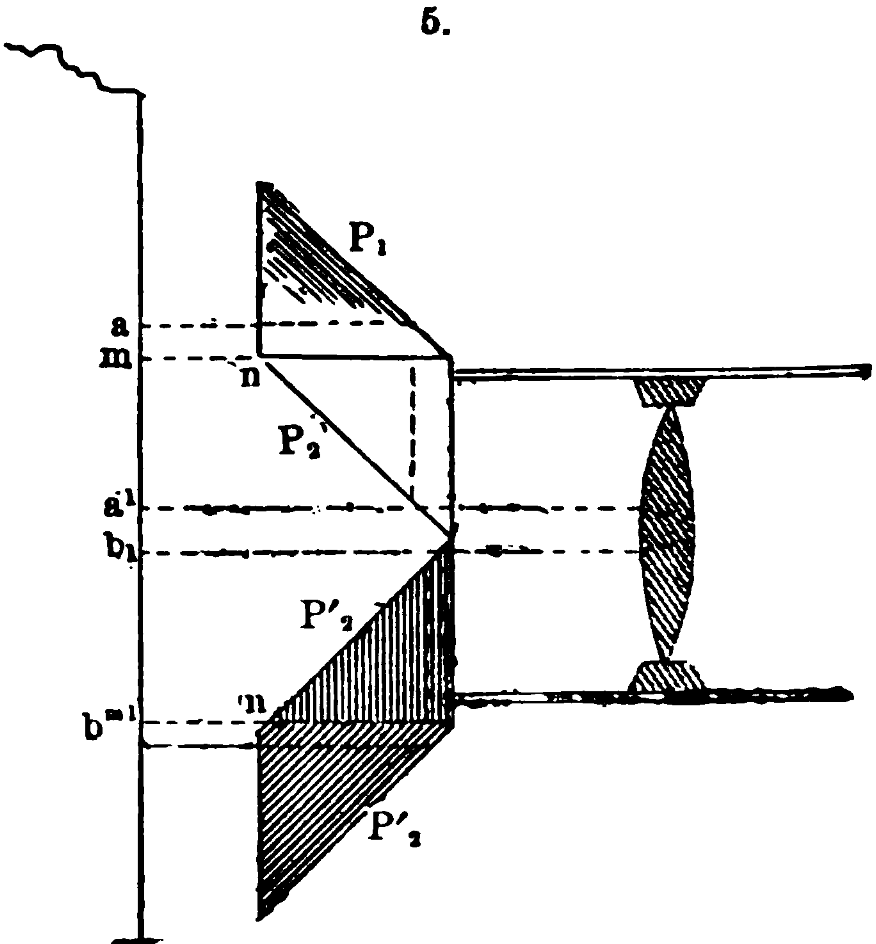


The two end-points a and b (fig. 5) of the bit of wire to be measured, were, as already stated, about 45^{mm} apart; and some especial contrivance was therefore necessary to bring both of them at once into the field of the opthalmometer. A system of rectangular prisms $P_1 P_2 P'_1 P'_2$ arranged as shown in fig. 5 served this end. After two total reflections the images $a_1 b_1$ were nearly coincident. Angle readings with the opthalmometer are only possible to tenths of a degree, and I found that $6'$ corresponded to a distance of $0{\cdot}003^{mm}$. To obtain greater delicacy I made use of a biconvex lens of as great magnifying power as the case permitted. There was a limit to the possible enlargement, since with too large an image the expansion

of the wire when heated sufficed to carry its ends out of the field of vision. In order that any unsteadiness of the wire might remain without influence on the measurements, the lens was attached, not to the opthalmometer, but together with the set of prisms upon the iron holder of the wire, so that possible jarring would effect rather the position than the size of the image. The second advantage of the instrument, that the reduction of angle readings to linear distances is the same whatever be the distance of the object from the eye, unfortunately disappears when the lens is used. The apparent distance between the images $a_1 b_1$ changes with the distance of the opthalmometer from the lens so that it was necessary to adjust the instrument once for all, and to keep it unchanged during the entire series of experiments. When a lens is used, the formula (5) instead of giving the real distance $a_1 b_1$, expresses merely the apparent distance between the images of a and b in the field of sight. The simplest modification consists in substituting another constant, which we shall denote by c for σ. The value of this constant was determined by exchanging the wire for a millimeter scale and noting the angles corresponding to displacements of the double images of $\frac{1}{8}$, $\frac{1}{4}$, etc., divisions of this scale. The scale was of boxwood and the half millimeters were marked by fine lines. The following table gives the angles corresponding to linear displacements of $\frac{1}{8}$, $\frac{1}{4}$, etc. millimeters. Each result is the mean of six readings.

TABLE III.

S	i
0·125^{mm}	17° 3′ 0″
0·250	32 24 0
0·375	44 54 0
0·500	55 22 12
0·625	64 46 12
0·750	72 28 12

If in formula (5) c is substituted for σ and values from the above table for S and i, we obtain, n being known, from the equation,

$$S\sqrt{1-\frac{\sin^2 i}{n^2}}=c\sin i\left(\sqrt{1-\frac{\sin^2 i}{n^2}}-\frac{\cos i}{n}\right) \qquad (6)$$

the numerical solution,

$$c=1{\cdot}03097^{mm}.$$

All the data necessary to the measurement of the distance $a_1 b_1$ were thus at hand. The distance $a b_1$ (fig. 5) is, however, $a_1 b_1 + m m_1$. Now the points m and m_1 are coincident in the field of the opthalmometer, appearing to lie at m_2; and their real distance can be measured by simply observing the double images of the above-mentioned scale as they appeared in the

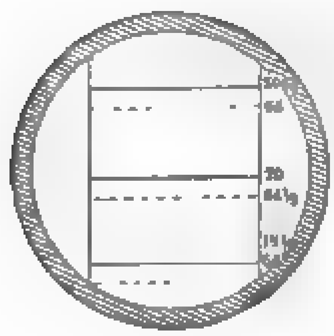
field of sight. Images of two parts of the scale were brought by total reflections in the set of prisms into the field (see fig. 6), the portion lying between divisions 19½ and 20½, and overlapping this the portion from division 64 to 65. Now turning the plates of the opthalmometer until the lines 20 and 64·5 coincided, which occurred when the angle was, according to three successive readings, 29°·12′. 29°·18′. 29°·12′, sufficed to show how much the distance $m\,m_1$ exceeded $44{\cdot}5^{mm}$.

From formula (6) we find,

$$\overline{m\,m_1} = 44{\cdot}55748^{mm},$$

to which quantity it was only necessary to add for any state of the wire the directly obtainable value $a_1\,b_1$, in order to know $a\,b$, the length of the piece of wire in question.

6.



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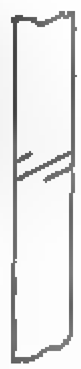

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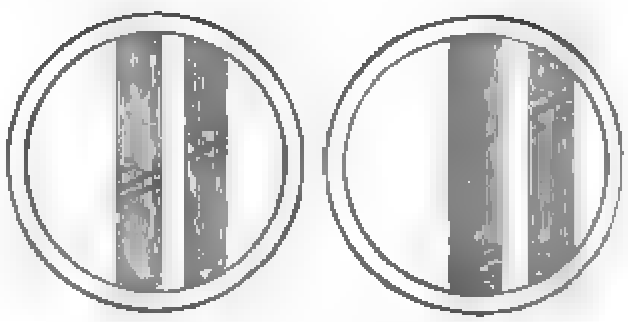


Cold wire. Hot wire.

Having chosen a and b as the end points of the wire to be measured, it was necessary in some way to mark them, so that when the wire was magnified the boundary lines should appear sharp, and at the same time be uninfluenced by the highest temperatures to which the metal was to be submitted. An indentation, be it ever so fine, will not only influence the temperature of the wire, but will even cause it to melt and break before the other portions have acquired the proper degree of heat. A ridge has the opposite effect, causing, in consequence of the increased conductive power, a dark ring upon the glowing metal. I employed, among other devices, minute glass beads, fused upon the wire in the desired places. This plan served very well at low temperatures, as it gave sufficiently sharp boundaries of demarkation; but as the heat increased, the melting of the glass next the metal destroyed the fineness of the boundary. It even happened at times that the entire bead would slip along to a new position on the wire. The following method, on the contrary, answered admirably. At the proper points simple loops of exceedingly thin platinum wire* ($0{\cdot}03^{mm}$ in diameter) were thrown around the larger wire. The latter having been brought to a white heat by means of the current, the loops were drawn tight at their appointed places. The

* This wire is prepared for use in the construction of electrometers.

small wire, fine as a fiber of raw silk, and scarcely visible to the naked eye, melted on touching the hot metal and became fixed upon its surface. The whole, seen through the microscope, appeared as in figs. 7 and 8. Since all the observations were made in a dark room, where, in the case of the cold wire, the marks would have been invisible, two small gas-flames were so placed that their rays, reflected from the loops of wire, appeared in the dark field of vision like two fine points of light. Such was the apparatus by means of which the temperatures given in the table of results were measured. It afforded all desired accuracy. The opthalmometer is free from many errors which by cathetometric and micrometric measurements are unavoidable.

The temperatures used varied from 1200° to 1900° of the platinum thermometer. Shortly after passing the latter point the platinum suffered a change of condition. It did not melt; but the wire lost its stiffness, hung down limp, scarcely holding together, and quivered when jarred like jelly. Under these circumstances measurements became unreliable. The very small weight* which hung at the lower end sufficed, as soon as the current became a trifle stronger, to stretch the wire in its weakest place. The conducting power being thus diminished, the temperature would rise very rapidly until after glowing brilliantly for a moment, the platinum would melt and the wire break.

IV.

Before the beginning of the experiments the two wires were adjusted in their iron holders before the slit of the spectrophotometer, which having been brought into its proper place and sealed fast, was not moved during the whole course of the investigation. The opthalmometer also, having been placed in the position most advantageous for the measurement of the expansion of the platinum wire, remained undisturbed throughout all the experiments. The leucoscope was set up two meters distant from the two wires.

The galvanic circuits of which the wires formed a part having been closed, and the few minutes necessary for the attainment of a constant temperature having elapsed, the deflection of the galvanometer and the condition of the constant wire as indicated by the leucoscope were noted. The temperature of the other wire was determined by the method described in

* If both ends of a cold platinum wire be fastened, and the wire be made to glow, the expansion resulting from this change of temperature suffices to move its center considerably from its original position. To avoid disturbance from this cause I fastened only one end of my wires, and inserted the lower ends into short copper rods, which dipped into small vessels of mercury. To prevent heating, the mercury vessels were placed in cold water.

the last paragraph, and then the spectro-photometric comparison of the rays emitted by the two wires carried out as rapidly and accurately as possible. Beginning with the wave lengths denoted by the scale-division 8 (see Table II), this being the point nearest the red end of the spectrum at which satisfactory results could be obtained, the intensities of the two spectra were compared in the spectral regions corresponding to divisions 9, 10, etc., to 19 in the neighborhood of line G_1 successively. Beyond 19 no accurate readings were possible.* The same measurements were then made in reverse order, from violet to red, and finally a second time from red to violet, and the mean values of these readings used.

After the completion of these readings the temperature of the wire was again taken, first in its glowing condition, and then, the circuit having been broken and time allowed for cooling, while cold. The deflections of the galvanometer and the temperature of the room were next noted, and last of all the constant wire again observed through the leucoscope. Whenever a difference in the measurements before and after an experiment pointed to a change of temperature in either wire, the experiment was set aside as imperfect.

The readings given in the following table will suffice to show the general character of the measurements.

TABLE IV.†

Scale-divisions.	Readings.	Mean.	90° — α.	Intensity.
8	37°·0 36 ·8 37 ·2	37°·00	20° 36′ 0″	·1238
9	36 ·0 36 ·3 36 ·0	36 ·10	19 42 0	·1136
10	32 ·5 33 ·5 32 ·9	32· 97	16 34 12	·08133
11	30 ·0 30 ·0 31 ·0	30 ·33	13 56 0	·05798
12	29 ·0 28 ·9 29 ·0	28 ·97	12 34 12	·04736
13	27 ·5 27 ·4 27 ·0	27 ·30	10 54 0	0·3576

* For the lower temperatures used, the spectrum was not visible even to line G. and measurements could only be carried out up to the scale-division nearest the limit of the visible rays.

† The figures in the column marked "Readings" denote the position of the pointer attached to the ocular Nicol. Subtracting from the mean of these readings for each part of the spectrum the position of the pointer when the Nicols are crossed, the quantity 90° — α is obtained. 90° — α being the angle between the planes of polarization of the two Nicols.

Scale-divisions.	Readings.	Mean.	90° − a.	Intensity.
14	25 ·9 26 ·7 26 ·4	26 ·33	9 56 0	·02976
15	24 ·0 23 ·3 24 ·3	23 ·87	7 28 12	·01696
16	24 ·0 23 ·5 24 ·0	23 ·83	7 25 48	·01600
17	....	....	....	....
18	....	....	....	....
19	....	....	....	....

From the 17th division onward the intensities were too small to allow of further measurements.

The other readings in the above experiment were as follows:

Before.

Leucoscope-readings		40°·6	40°·3
Opthalmometer-readings (for the hot wire,		56°·5	

After.

Leucoscope-readings		40°·5	40°·4
Opthalmometer-readings (for the hot wire)		56 ·5	56 ·5
Opthalmometer-readings (for the cold wire)	29°·4	29°·5	29°·5
Movement of the galvanometer during the experiment*			4cm
Temperature of the room			20°·1 C.

Applying the above readings in formula (6) we find as temperature of the hot wire 1539°·5 (of the platinum thermometer). I succeeded in obtaining thirteen such series of measurements at temperatures varying from 1932° to 1201°,† and covering wave lengths from scale-division 8 and the end of the visible spectrum in the direction of the violet. These results are given in the column marked "Observed," Table V. They can be approximately represented by curves the abscissæ of which are temperatures and whose ordinates are the corresponding quantities in the column marked "Calculated." The differences between the observed and calculated values are given in a separate column.

Table V.

Region 8 on Kirchhoff's Scale 609·1.

Temp. (°)	Observed.	Calc.	Diff.	Temp. (°)	Observed.	Calc.	Diff.
1201·1	0·001	0·004	+·006	1628·8	0·290	0·288	+·002
1256·9	0·006	0·005	+·001	1653·0	0·383	0·350	+·033
1358·3	0·041	0·026	+·015	1759·6	0·623	0·623	·000
1426·4	0·030	0·037	+·007	1901·7	1·421	1·417	+·004
1539·5	0·123	0·145	−·008	1932·7	1·760	1·959	+·001
1618·5	0·288	0·257	+·037				

* A movement of the spot of light over 1·25 meters corresponded to a change of temperature in the wire sufficient to be detected by the leucoscope. 4cm denoted a negligible decrease in temperature.

† Draper (Philosophical Magazine, xxx. 345) gives 525° C. as the point of temperature at which visible rays begin to appear. Granting the accuracy of this measurement, we find a long interval of at least 600° within which the intensity of even the red rays is exceedingly small compared to their intensity at 1900°. So far as the present method goes, they are immeasurably small.

Region 9 on Kirchhoff's Scale 813.

Temp. (°)	Observed.	Calc.	Diff.	Temp. (°)	Observed.	Calc.	Diff.
1201·1	0·004	0·003	+·001	1653·0	0·295	0·296	—·001
1256·9	0·004	0·004	·000	1689·7	0·341	0·389	—·048
1358·3	0·003	0·020	—·0165	1759·6	0·580	0·582	—·002
1426·4	0·0185	0·033	—·015	1901·7	1·411	1·409	+·002
1539·5	0·113	0·105	+·008	1932·7	1·740	1·739	+·001
1618·5	0·241	0·230	+·011				

Region 10 on Kirchhoff's Scale 1007.

1201·1	0·004	0·0028	+·0012	1628·8	0·207	0·216	—·009
1256·9	0·003	0·0035	—·0005	1653·6	0·249	0·257	—·008
1358·3	0·023	0·018	+·005	1759·6	0·572	0·565	+·007
1426·4	0·0162	0·025	—·0088	1901·7	1·395	1·370	+·025
1539·5	0·081	0·086	—·005	1932·7	1·698	1·695	+·003
1618·5	0·199	0·198	+·001				

Region 11 on Kirchhoff's Scale 1221.

1201·1	0·003	0·0025	+·0005	1628·8	0·204	0·197	+·007
1256·9	0·003	0·003	·000	1653·6	0·241	0·240	+·001
1358·3	0·0181	0·0125	+·0056	1689·7	0·307	0·314	—·007
1426·4	0·0151	0·0189	—·0038	1759·6	0·545	0·536	+·009
1504·8	0·048	0·047	+·001	1901·7	1·339	1·330	—·011
1539·5	0·058	0·076	—·018	1932·7	1·668	1·666	+·002
1618·5	0·170	0·170	·000				

Region 12 on Kirchhoff's Scale 1422.

1201·1	0·003	0·002	+·001	1618·5	0·130	0·135	—·005
1256·9	0·002	0·0025	—·0005	1653·6	0·220	0·200	+·020
1358·3	0·014	0·010	+·004	1689·7	0·267	0·271	—·004
1426·4	0·013	0·012	+·001	1759·6	0·523	0·486	+·037
1504·8	0·0139	0·0136	+·0003	1901·7	1·375	1·313	+·002
1539·5	0·047	0·063	—·016	1932·7	1·666	1·665	+·001

Region 13 on Kirchhoff's Scale 1629.

1201·1	0·002	0·0015	+·0005	1628·8	0·154	0·140	+0·14
1358·3	0·008	0·007	+·001	1653·6	0·161	0·173	—·012
1426·4	0·009	0·008	+·001	1689·7	0·236	0·240	—·004
1504·8	0·035	0·020	+·015	1901·7	1·225	1·225	·000
1539·5	0·036	0·038	—·002	1932·7	1·620	1·610	+·010
1618·5	0·109	0·125	—·016				

Region 14 on Kirchhoff's Scale 1833.

1201·1	0·001	0·001	·000	1653·6	0·154	0·151	+·003
1358·3	0·006	0·005	+·001	1689·7	0·208	0·210	—·002
1426·4	0·007	0·007	·000	1759·6	0·409	0·400	+·009
1504·8	0·029	0·022	+·007	1901·7	1·180	1·176	+·004
1618·5	0·091	0·101	—·010	1932·7	1·595	1·590	+·005
1628·8	0·133	0·118	+·015				

Region 15 on Kirchhoff's Scale 2037.

1358·3	0·005	0·005	·000	1628·5	0·114	0·099	+·015
1426·4	0·006	0·006	·000	1653·6	0·153	0·130	+·023
1504·8	0·019	0·013	+·006	1759·6	0·351	0·350	+·001
1539·5	0·018	0·015	+·003	1901·7	1·150	1·146	+·004
1618·8	0·073	0·080	—·007	1932·7	1·550	1·550	·000

Region 16 on Kirchhoff's Scale 2241.

1358·3	0·004	0·004	·000	1628·8	0·074	0·069	+·005
1426·4	0·006	0·005	+·001	1689·7	0·132	0·133	—·001
1504·8	0·013	0·010	+·003	1759·6	0·304	0·304	·000
1539·5	0·017	0·017	·000	1901·7	0·959	0·960	—·001
1618·5	0·067	0·059	+·008	1932·7	1·506	0·508	—·002

Region 17 on Kirchhoff's Scale 2445.

Temp. (°)	Observed.	Calc.	Diff.	Temp. (°)	Observed.	Calc.	Diff.
1504·8	0·010	0·009	+·001	1759·6	0·290	0·280	+·010
1539·5	0·017	0·015	+·002	1901·7	0·891	0·891	·000
1618·5	0·054	0·056	−·002	1932·	1·320	1·321	−·001
1689·7	0·108	0·108	·000				

Region 18 on Kirchhoff's Scale 2648.

Temp. (°)	Observed.	Calc.	Diff.	Temp. (°)	Observed.	Calc.	Diff.
1653·6	0·067	0·050	+·017	1901·7	0·795	0·799	−·004
1689·7	0·112	0·080	+·032	1932·7	1·249	1·249	·000
1759·6	0·274	0·240	+·034				

Region 19 on Kirchhoff's Scale 2853.

Temp. (°)	Observed.	Calc.	Diff.	Temp. (°)	Observed.	Calc.	Diff.
1689·7	0·060	0·059	+·001	1901·7	0·750	0·750	·000
1759·6	0·207	0·202	+·005	1932·7	1·203	1·200	+·003

The size of the above differences bears witness to the difficulties which, aside from those which are unavoidable, even in the study of the most favorable colors at intensities best adapted to the eye, stand in the way of accurate results. At the lowest temperatures, where the weaker spectrum had only a few thousandths the intensity of the other, exactness was quite out of the question. How vastly the eye varies in delicacy according to the color of the light, is shown by the following measurements of the intensity of various rays necessary to produce in the eye the perception of color. One finds upon turning the ocular Nicol from the position of maximum brightness to that where the ray becomes completely extinguished, that in the case of the red rays on the one hand and of the blue and violet on the other, this point is much sooner reached than with the yellow and green rays. The position of the ocular Nicol, at which each ray of the spectrum disappears, is given in the column marked "$90° - \alpha$" of table VI. The corresponding intensities are shown under "$\sin^2(90-\alpha)$" and in the column marked "optical action" is given the power of the respective rays upon the eye.

TABLE VI.

Region.	$(90-\alpha)°$	$\sin^2(90-\alpha)$	Optical action.	Region.	$(90-\alpha)°$	$\sin^2(90-\alpha)$	Optical action.
7	7·32	0·01719	0·1782	14	3·54	0·04620	0·0662
8	1·45	0·00932	0·3284	15	5·0	0·07592	0·0432
9	1·6	0·00363	0·6601	16	7·24	0·16560	0·0184
10	1·0	0·00306	1·0000	17	8·30	0·21600	0·0142
11	2·6	0·01340	0·2281	18	9·36	0·27801	0·01117
12	2·18	0·01611	0·1900	19	12·36	0·44662	0·0068
13	2·42	0·02221	0·1380	20	15·36	0·72320	0·0023

These results are introduced here, to show with what immense subjective differences we have to do in studying the visible spectrum. However valuable such researches might prove to show remarkable variations of the eye with regard to its perceptive power for various colors, these very changes render the experiments useless in the investigation of the real energy of the rays themselves.

In table V the intensities of the various wave lengths for all the temperatures in question are expressed in terms of the intensities of corresponding wave lengths of a similar spectrum of constant but unknown temperature. For each individual ray, the measurements give the change of intensity resulting from a given change of temperature; but since the relative intensity of the various wave lengths of the spectrum of constant temperature are unknown, it is impossible to compare rays of different wave length with each other.

Before describing the way in which all the above results were reduced to a common basis for the purpose of comparison, a clear definition of the expression "intensity of ray" as used in this paper is desirable.

It is first of all essential to distinguish between the intensity of the ray itself and the intensity of its various effects upon bodies upon which it may fall. It is usual to define as the intensity of the ray itself, its energy of vibration or the square of the amplitude of vibration. Kirchhoff however (§ 2 of his above mentioned treatise), defines as the energy of the ray passing the openings of the screens S_1 and S_2 (fig. 1) the increase in a unit of time of the vis viva of the ether behind the second screen. This definition is the more appropriate to the case at hand. Suppose that for the opening S_2 a black body be substituted. In accordance with the principle of the Conservation of Energy, as expressed in the usual equation,

$$T_1 - T_0 = \int_{t_0}^{t_1} \Sigma (X\,dx + Y\,dy + Z\,dz) = U_1 \qquad (7)$$

where T_1 and T_0 are the energy (*lebendige Kraft*) before and after the interval of time, and U_1 denotes the work performed: the increase in energy in the body equals in the unit of time, the work performed by the action of the ray. We may then consider this work as the measure of the intensity of the ray itself. Suppose further, the body be molecularly so constituted that no chemical action takes place, that in short the entire energy of the ray be converted into heat. The amount of heat produced may in this case be taken as the measure of the intensity of the ray itself. This heat, as denoted by the change of temperature of the body, is the result of what is termed the thermal action of the ray, so that the intensity of the ray itself, which I shall call the *mechanical intensity of the ray*, because it is directly expressible in units of work,—is proportional to the intensity of the thermal action, or the *thermal intensity of the ray*.

The *chemical** and *optical intensities of the ray* stand in as yet

* Clerk Maxwell, Theory of Heat, p. 240, offers a very ingenious suggestion as to the real nature of the chemical action of light. "It is probable that when the radiation produces the photographic effect, it is not by its energy doing work on the chemical compound, but rather by a well-timed vibration of the molecules dis-

unknown relation to the mechanical intensity. They are only known in connection with a small class of substances, the optical action seeming to affect a single body only (the retina of the eye). They occur only in certain limited sets of rays, and depend largely for their effect upon the nature and condition of the body acted on. They are therefore useless as measures of the mechanical intensity.

The intensities given in Table V are, however, simply expressions for the square of the amplitudes, and therefore directly proportional to the thermal actions of the respective rays. The thermal intensities of these rays being, at the temperatures available, too small for direct measurement, the easiest way of determining their values is by making a spectrophotometric comparison with the corresponding rays of the sun's spectrum, the thermal intensities of which have been most carefully measured. The best determinations of the sun's spectrum are by Lamansky,* whose results for the visible rays, with the dispersion of a crown-glass prism, are, when adapted to the scale used in my researches as follows:

TABLE VII.

Region.	On Kirchhoff's Scale.	Thermal Intensity.	Region.	On Kirchhoff's Scale.	Thermal Intensity.
8	609·1	0·826	14	1832	0·302
9	813	0·703	15	2037	0·245
10	1017	0·605	16	2241	0·200
11	1221	0·530	17	2445	0·163
12	1422	0·453	18	2628	0·130
13	1629	0·375	19	2853	0·099

The unit in this table is the intensity at the point of maximum heat for the whole spectrum, which lies beyond the last of the visible red rays.

The comparison of the sun's spectrum with that of the platinum wire was made in this way. Diffuse daylight—as reflected from white clouds was used instead of the direct rays of the sun, repeated trials with the leucoscope having shown these to be of identical composition. The pencil of this light was substituted for the rays from the platinum wire of constant temperature. The other wire was given a temperature of 1607° (platinum thermometer), and the measurements were made in a manner precisely similar to that already described. Table VIII contains the readings and results of this comparison.

lodging them from the almost indifferent equilibrium into which they had been thrown by previous chemical manipulations, and enabling them to rush together according to their more permanent affinities so as to form stabler compounds." If this be true, we have evidently to do with work arising from energy stored up by previous chemical action, and therefore not all ascribable to the energy of the ray.

* Lamansky, Poggendorff's Annalen, cxli.

TABLE VIII.

Comparison of the sun's spectrum with that of glowing platinum.

Region.	Reading.	Mean.	9° − a.	Intensity.
8	106°·3, 106·5, 106·4	106°·4	90° 0′	1·000
9	99·0, 98·4, 99·6	99·0	72 36	0·91057
10	67·0, 68·0, 67·5	67·5	51 6	0·60570
11	45·0, 44·0	44·5	28 6	0·22185
12	37·0, 37·0	37·0	20 36	0·12380
13	31·9, 32·9	32·4	16 0	0·07600
14	30·0, 30·0	30·0	13 36	0·05529
15	27·5, 27·0	27·25	10 43	0·03457
16	26·2, 25·8	26·0	9 36	0·02781
17	23·9, 24·0	23·95	6 33	0·01300
18	22·1, 21·9	22·0	5 36	0·00951
19	20·0, 20·0	20·0	3 36	0·00394

With the help of these measurements and of Lamansky's results just given, the intensities of the platinum spectrum for the various temperatures can be reduced to a common unit, and the results in this new form made to express not only the influence of temperature upon each ray considered separately, but, what is equally important, the relations between the intensities of all visible wave lengths by constant temperature.

Using the values, in the column marked "calculated" (Table V), I have constructed a table which gives for intervals of 25°, from 1200° to 1900° (platinum thermometer), the intensities corresponding to the wave lengths between scale-divisions 8 to 19 in terms of the intensity of the spectral-region corresponding to division 10 when the platinum was at 1900°.

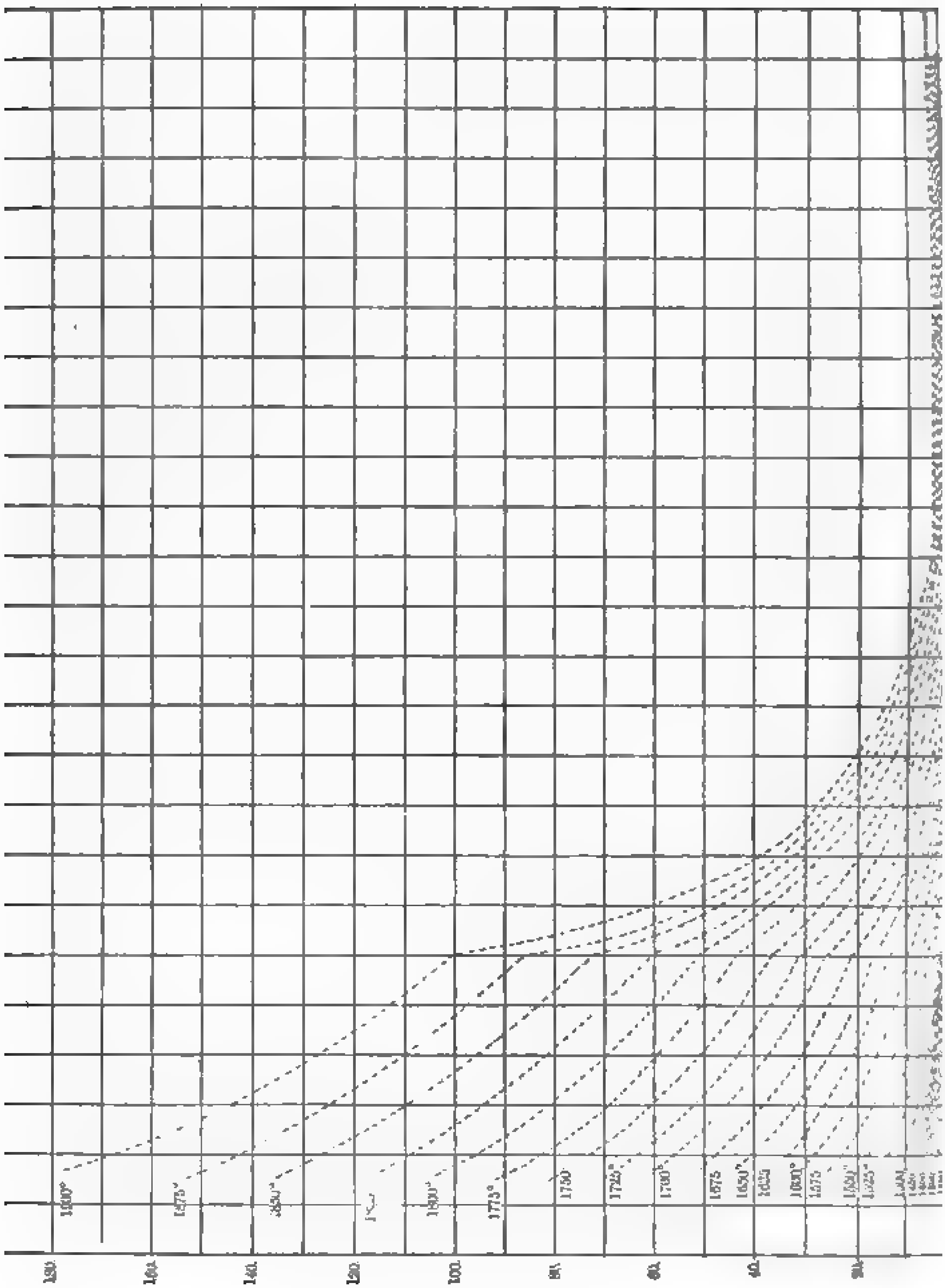
This value was chosen as the unit because the position of division 10 could be simply and accurately defined. This region corresponds so nearly with line D, that it may be defined as *the region bordering on line D, on the side nearest the violet.* This table (IX) which may be, not inaptly, termed *Isothermic*, is arranged according to temperatures.

TABLE IX (Isothermic).

Regions.		Intensity.							
		1900°	1875°	1850°	1825°	1800°	1775°	1750°	1725°
8 or	609·1mm	1·7071	1·4285	1·234	1·078	0·9470	0·830	0·732	0·637
9	813	1·2102	1·026	0·874	0·748	0·6322	0·552	0·480	0·416
10	1017	1·0000	0·852	0·721	0·606	0·5147	0·436	0·379	0·322
11	1221	0·3665	0·315	0·269	0·257	0·1844	0·150	0·123	0·096
12	1422	0·1975	0·163	0·149	0·115	0·0946	0·076	0·064	0·055
13	1629	0·1086	0·089	0·076	0·063	0·0512	0·042	0·034	0·027
14	1833	0·0758	0·058	0·052	0·046	0·0351	0·030	0·025	0·019
15	2037	0·0445	0·036	0·033	0·027	0·0216	0·018	0·016	0·013
16	2241	0·0391	0·027	0·024	0·020	0·0176	0·013	0·010	0·008
17	2445	0·0282	0·019	0·015	0.013	0·0123	0·006	0·005	0·004
18	2648	0·0256	0·014	0·011	0·009	0·0108	0·003	0·0025	0·002
19	2853	0·0160	0·008	0·005	0·004	0·0071	0·0015	0·0012	0·0007
		1700°	1675°	1650°	1625°	1600°	1575°	1550°	1525°
8 or	609·1mm	0·5512	0·472	0·395	0·326	0·2719	0·214	0·169	0·131
9	813	0·3667	0·304	0·256	0·210	0·1694	0·128	0·100	0·076
10	1017	0·2774	0·228	0·187	0·155	0·1221	0·092	0·068	0·052
11	1221	0·0668	0·052	0·042	0·033	0·0277	0·023	0·020	0·016
12	1422	0·0447	0·037	0·027	0·021	0·0183	0·0170	0·015	0·007
13	1629	0·0238	0·016	0·014	0·012	0·0093	0·007	0·006	0·004
14	1833	0·0131	0·012	0·009	0·006	0·0054	0·003	0·0025	0·0015
15	2037	0·0075	0·007	0·005	0·004	0·0027	0·0025	0·0020	0·0010
16	2241	0·0061	0·005	0·002	0·002	0·0018	0·0016	0·0013	0·0007
17	2445	0·0037	0·0005	0·0009	0·0009	0·0007	0·0007	0·0005	0·0004
18	2648	0·0029	0·0006	0·0005	0·0004	0·00025	0·00022	0·0020	0·0001
19	2853	0·0017	0·0004	----	----	----	----	----	----
		1500°	1475°	1450°	1425°	1400°	1875°	1350°	1325°
8 or	609·1mm	0·0922	0·067	0·056	0·047	0·0388	0·032	0·027	0·022
9	813	0·0576	0·046	0·037	0·028	0·0227	0·0170	0·0119	0·0113
10	1017	0·0382	0·029	0·026	0·020	0·0176	0·0121	0·011	0·008
11	1221	0·0120	0·0113	0·011	0·009	0·0043	0·004	0·004	0·003
12	1422	0·0046	0·003	0·0025	0·002	0·0018	0·0015	0·0012	0·0003
13	1629	0·0019	0·001	0·0008	0·0005	0·0015	0·0004	0·00035	0·00021
14	1833	0·0009	0·0007	0·0005	0·0002	0·00019	0·00017	0·00015	0·00010
15	2037	0·0005	0·0004	0·0003	0·00015	0·00007	0·00006	0·0005	----
16	2241	0·0002	0·00017	0·00014	0·00009	0·00004	----	----	----
17	2445	0·0006	0·0006	. .	----	----	----	----	----
18	2648	0·0003	----	----	----	----	----	----	----
19	2853	----	----	----	----	----	----	----	----
		1300°	1275°	1250°	1225°	1200°	....	....	....
8 or	609·1mm	0·0182	0·017	0·015	0·012	0·0097	----	----	----
9	813	0·0096	0·008	0·006	0·005	0·0043	----	---	----
10	1017	0·0046	0·004	0·002	0·0018	0·0013	----	----	----
11	1221	0·0009	0·0007	0·0006	0·0005	0·00038	----	----	----
12	1422	0·0002	0·00015	0·0001	----	----	----	----	----
13	1829	0·0000	0·00007	----	----	----	----	----	----
14	1833	----	----	----	----	----	----	----	----

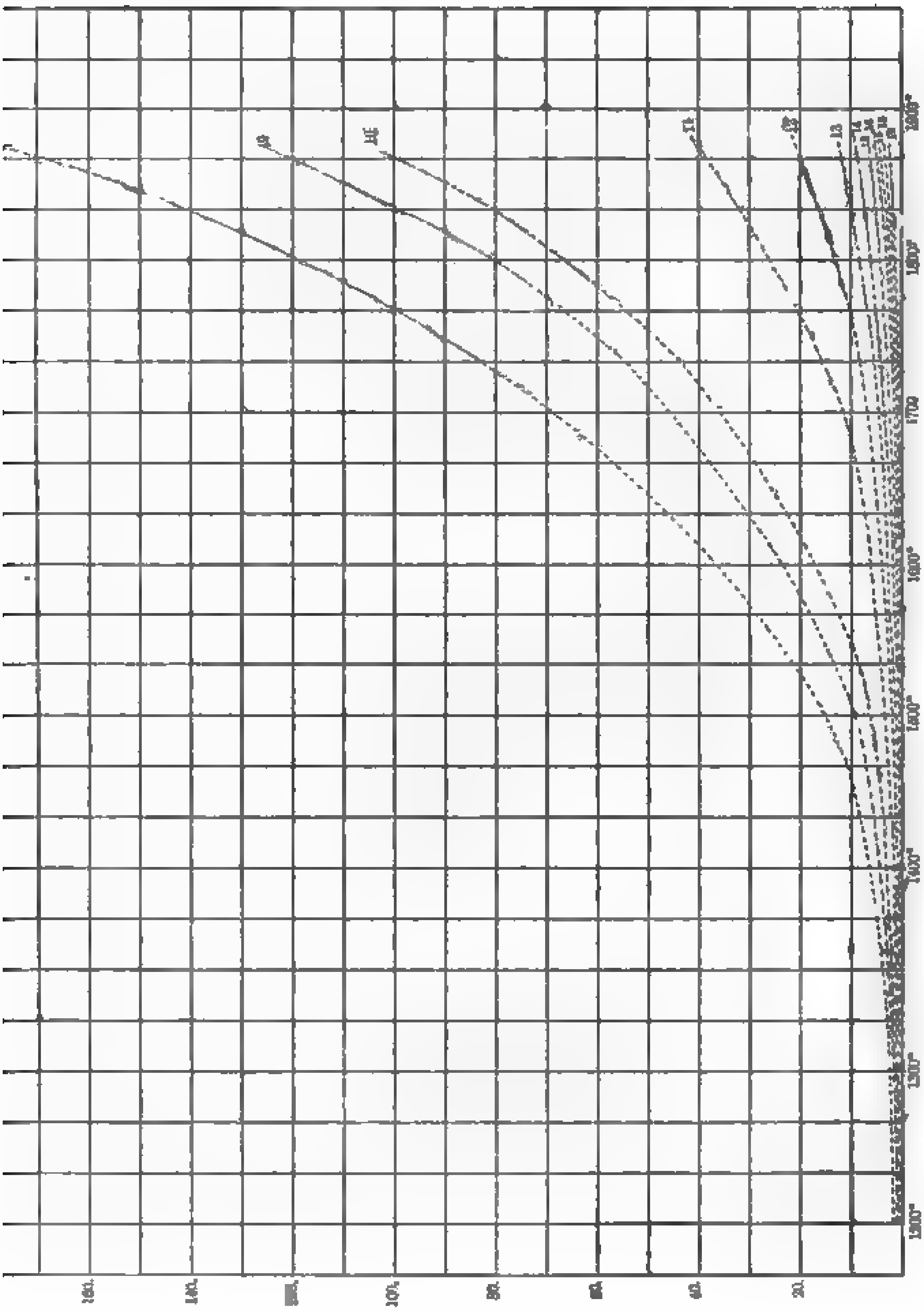
The two sets of curves constructed from this table serve to render the character of these results more evident. In Diagram A, are drawn *Isothermals*, curves of equal temperature, in which the abscissæ are wave lengths, the ordinates intensities. Diagram B, gives the *Isochromatics*, or curves of equal wave lengths, with temperatures as abscissæ and intensities as ordinates. The first set shows the

Diagram A.



Isothermals.

Diagram B.



Isochromatics.

comparative intensities of the various parts of the visible spectrum by constant temperature, the latter denotes the influence of variations of temperature upon the intensity of each individual series of rays.

How exceedingly small the intensity of the more refrangible rays is, even at 1900°, compared with that of the spectral regions between line D and the red end of the spectrum, is equally evident in both sets of curves. A striking peculiarity of the isothermals is the too large value of the intensity of region (10). This unlooked-for feature can scarcely be due to a corresponding irregularity in the platinum spectrum, and at the same time it is in all probability no accidental error. Such an error, in order to produce such an effect in *all* the isothermic curves, must be looked for either in my comparison of the sun's spectrum with that of the platinum wire, or in Lamansky's measurements of the sun's heat. As to the former, we find by reference to the table, that the result in question is calculated from the mean of three readings of fair agreement. An error of several degrees in these determinations would be necessary to bring about any such irregularity as exists in the curves. Lamansky's results are also the mean of numerous measurements, and the occurrence of so large an error just at this point would at once be detected.

A curious fact recorded by Vierordt* while studying the spectra of gases, offers, I think, the true explanation of the irregularity. He observed, that even in absorptions-spectra, with clearly defined lines, no real discontinuity in the intensity of contiguous rays occurs, that, on the contrary, very sudden, but perfectly continuous, changes take place at the edge of each bright or dark line. The region (10) corresponds however, to the edge of the line D, (see pages 13 and 40), and would consequently in the sun's spectrum be weaker, owing to the proximity of the absorption line, than in a perfectly continuous spectrum. In the platinum spectrum, on the other hand, this region would possess its normal brightness, or in case, as generally happens, the surrounding atmosphere contained a trace of sodium, would form the edge of a bright line D, and be of more than normal intensity. This fact would tend, in the comparison of the spectra, to the production of just such an irregularity as appears in the curves on Diagrams A and B.

Kirchhoff, in his treatise (§ 15), draws the following *à priori* conclusions from his discussion:

"If a body, a platinum wire for example, is gradually heated, it emits until attaining a certain temperature, only rays the wave lengths of which are greater than those of the visible spectrum. At a certain temperature, rays of wave lengths cor-

* Vierordt, Poggendorff's Annalen, 151.

responding to the extreme red begin to appear. As the body becomes hotter and hotter, rays of shorter and shorter wave lengths show themselves, so that for each temperature a new set of rays first makes its appearance, while at the same time, the intensity of those already at hand continues to increase. Applying the principle we have already proved to this case, we see that the function I for any given wave length is equal to 0 for all points below a certain temperature corresponding to this wave length; and that for all temperatures above this point, the function I increases with the temperature."

Strictly speaking, however, the temperature at which each individual wave length becomes visible depends solely upon the sensitiveness of the observer's eye. We are furthermore forced to conclude from the experiment recorded in table VI, that the more refrangible rays really exist at temperatures far below those at which we begin to see them. The directions of the curves (Plates I and II) seem to denote, that all the rays studied begin to be emitted at some temperature not included in the interval embraced by the experiments. I suspect indeed that all of them originate at some very low degree (the absolute zero?) and are recognizable no sooner, simply because the various instruments at command, the thermopile, eye, photographic plate, etc., are not more delicate. That the various colors do not appear simultaneously, follows from the very different degrees of sensitiveness shown by the eye for different rays.

A fuller discussion of the results given in this paper, of their application in the study of the function I, and of an optical method, based upon them, for the measurement of high temperatures, will be given in another article. I will conclude with a single remark concerning the scale of temperatures used in this paper.

In view of the present ignorance of the law of expansion for platinum at high temperatures, it seemed better instead of trying to reduce my measurements to Celsius' degrees of the air thermometer, to constitute by means of a simple definition a scale for the platinum thermometer, which should be quite independent of other standards, and which could easily be expressed in terms of the existing scales so soon as the necessary investigations of the expansion of platinum had been made.

The already existing researches extend only over ordinary temperatures, and the empirical formulæ based upon them being only strictly applicable to the interval covered by actual experiment, a reduction obtained by use of them for an interval between the red heat and melting point would be at best of doubtful value. I give, nevertheless, such a reduction, founded

upon Matthiessen's* formula for the expansion of platinum between 0° C. and 200° C. This formula reads,

$$l = l_0 (1 + 0{\cdot}00000851\, t + 0{\cdot}0000000035\, t^2)$$

and the reductions are given in the following table:

TABLE X.

Platinum.	Celsius.	Platinum.	Celsius.
1900°	1294°	1500°	1081°
1800	1238	1400	1025
1700	1188	1300	968
1600	1129	1200	910

Of the accuracy of this comparison there are at present no means of deciding. Taking into consideration, however, the attempts already frequently made, to estimate the temperature of flames, glowing metal, etc., it seems likely that the above values, in degrees Celsius, are considerably too small.

Rosetti of Venice gives, for example, for the hottest portion of a Bunsen's burner flame, 1350°. According to Pouillet,† the melting points of various metals are as follows:

Wrought-iron	1600° C.		Cast-iron	1200 C.	1050° C.
Steel	1400 C.	1300° C.	Gold (pure) ..	1200 C., etc.	

Peekskill, N. Y., May 28, 1879.

ART. LVII.—*Notice of recent Additions to the Marine Fauna of the Eastern Coast of North America, No. 7*; by A. E. VERRILL. *Brief Contributions to Zoology from the Museum of Yale College.* No. XLIV.

AMONG the numerous additions recently made to the marine fauna of our coast by the fishermen of Gloucester, Mass., are two new species of Cephalopods. They both belong to the eight-armed division. One is a true *Octopus*. The other and more interesting one is the second known representative of the remarkable family of *Cirroteuthidæ*, characterized by the presence of a pair of fins, one on each side of the body, supported by a transverse cartilage; by the presence of a great web, surrounding and uniting all the arms, nearly to their tips; and by the presence of two slender cirri between the suckers, along the greater part of the length of the arms.

Our species differs so widely from *Cirroteuthis Mülleri* Esch., the only representative of the family hitherto described, that it is necessary to constitute for it a new genus.

Stauroteuthis, gen. nov.

Allied to *Cirroteuthis*, but with the mantle united to the head all around, and to the dorsal side of the slender siphon, which it surrounds like a close collar, leaving only a very narrow opening around the base of the siphon, laterally and ventrally.

* Matthiesen, Phil. Mag., VI, vol. xxxii. † Pouillet, Comptes Rendus, i, ii.

Fins triangular, in advance of the middle of the body. Dorsal cartilage forming a median angle directed backward. Body flattened, soft, bordered by a membrane. Eyes covered by the integument. Web not reaching the tips of the arms, the edge concave in the intervals. Suckers in one row. Cirri absent between the basal and terminal suckers. Right arm of second pair is altered, in the male, at the tip.

Stauro'euthis syrtensis, sp. nov.

♂. Head broad, depressed, not very distinct from the body. Eyes large. Body elongated, flattened, soft or gelatinous, widest in the middle, narrowed but little forward, but decidedly tapered, back of the fins, to the flat, obtuse, or subtruncate tail. The sides of the head and of the body, forward of the fins, are bordered by a thin soft membrane, about half an inch wide. The fins are elongated, triangular, obtusely pointed, placed in advance of the middle of the body. Siphon elongated, slender, round, with a small terminal opening. Mantle edge so contracted and thickened around its base as to show scarcely any opening, and united to it dorsally. Arms long, slender, subequal, each united to the great web by a broad membrane developed on its outer side, widest (about 1·5 inch) in the middle of the arm, while the edge of the web unites directly to the sides of the arms and runs along the free portion toward the very slender tip, as a border. This arrangement gives a swollen or campanulate form to the extended web. Edges of the web incurved between the arms, widest between the two lateral pairs of arms. The arms bear each fifty-five or more suckers, in a single row. Those in the middle region are wide apart (·5 inch or more) with a pair of slender, thread-like cirri, about 1 inch long, midway between them. The cirri commence, in a rudimentary form, between the 5th and 6th suckers, on the dorsal arms, and between the 7th and 8th, on the ventral ones. They cease before the 23d sucker on the dorsal and lateral arms, and before the 22d on the ventral ones. Near the mouth, and beyond the last cirri on the free portion of the arms, the suckers are more closely arranged. They are small, with a deep cavity. Color, in alcohol, generally pale with irregular mottlings and streaks of dull brownish; inner surface of arms and web, toward the base, and membrane around the mouth, deep purplish brown. Length from end of body to base of arms, 6·30 inches; length to posterior base of fins, 2·50; to anterior base, 4; width across fins, 5; in advance of fins, 2·70 (not including lateral membrane); across eyes, 1·75; across end of tail, 1·20; diameter of eye, 1; width of fins, at base, 1·20; their length, 1·75; length of arms, 13 to 14 inches; portion beyond web, 2·5 to 3 inches. Edge of extended web, between upper arms, about 4 inches; between lateral arms, about 8 inches; entire circumference of web, about 48 inches.

Taken by Capt. Melvin Gilpatrick and crew, schooner "Polar Wave," N. lat. 43° 54′; W. long. 58° 44′, on Banquereau, about 30 miles E. of Sable I., in 250 fathoms. Presented to the U. S. Fish Commission, Sept., 1879.

Octopus piscatorum, sp. nov.

Body of female is smooth, depressed, about as broad as long. Obtusely rounded posteriorly, not showing any lateral ridges, nor dorsal papillæ. No cirrus above the eyes. Arms long, rather slender, tapering to long, slender, acute tips, the upper ones a little (·1 of an inch) shorter than those of the second pair, which are the longest; the third pair are about one-half inch shorter than the second; the ventral pair about one-fourth inch shorter than the third. In our specimen all the arms on the right side are somewhat shorter than those on the left, and the web between the 1st and 2d arms is narrower, due perhaps to recovery from an injury. The suckers are moderately large, alternating in two regular rows, except close to the mouth, where a few stand nearly in a single line; about fourteen to sixteen are situated on the part of the arms included within the interbrachial web. The whole number of suckers on one arm is upwards of seventy. The web between the arms, except ventrally, is of about equal width, and scarcely more than one-fourth the length of the arms, measuring from the beak. Between the ventral arms the web is about half as wide as between the lateral.

Color of alcoholic specimen, deep purplish brown, due to very numerous crowded, minute, specks; eye-lids whitish. The front border of mantle, beneath, with base of siphon and adjacent parts, is white; end of siphon brown. Lower side of head and arms lighter than the dorsal side. Total length, from posterior end of body to tip of arms, of 1st pair, 6·20 inches; 2d pair, 6·30; 3d pair, 5·75; 4th pair, 5·25; to web between dorsal arms, 3·25; between ventral arms, 2·50; to edge of mantle, beneath, 1·20; to center of eye, 1·55. Breadth of body, 1·25; of head across eyes, 1·20; breadth of arms, at base, ·22; diameter of largest suckers, ·10; length of arms, beyond web, 1st pair, 3·00; 2d pair, 3·25; 3d pair, 2·80; 4th pair, 2·75.

Taken by Capt. John McInnis and crew of the schooner "M. H. Perkins," from the western part of Le Have Bank, off Nova Scotia, in 120 fathoms. Presented to the U. S. Fish Commission, Oct. 1879.

This species is easily distinguished from *O. Bairdii*, by its more elongated body, its much longer and more tapered arms, with shorter web; by the absence of the large, rough, pointed papilla, or cirrus, above the eyes, and by its general smoothness. The white color of the underside of the neck, siphon and mantle-border also appears to be characteristic.

ART. LVIII.—*Notes on the Geology of Galisteo Creek, New Mexico;* by JOHN J. STEVENSON, Professor of Geology in the University of the City of New York.

GALISTEO CREEK rises near the southern end of the Santa Fe mountains and flows southward for nearly fifteen miles to Galisteo; where, being increased by the Arroyo San Cristobal, coming from the east, it turns westward and flows in that direction to the Rio Grande. Its area is divided by a narrow dike, which forms a distinct ridge and separates the portion drained by the creek in its southward flow, from that drained by the Arroyo San Cristobal and the creek in its westward flow. These divisions may be distinguished as the upper and the lower area of the Galisteo. The region is not wholly unknown to geologists, for it has been visited by Dr. Newberry, Dr. Hayden and Professor Cope, whose views respecting the age of the coal beds and of the peculiar Galisteo sandstone are not in accord. The details of my observations there will be given in my report to Captain Wheeler; here, by consent of the Chief of the Engineer corps, U. S. A., a brief résumé of the results will be given, in so far as they bear upon the matters in dispute.

The shales of the Fort Pierre group (No. 4 of Mr. Meek's general section) are shown at barely sixteen miles below Galisteo dipping gently eastward in mesas on both sides of the creek. They have all the characteristic features of that group and yield its peculiar fossils at many localities. The Laramie group rests on them, and its western outcrop is reached on the south side of the creek at somewhat less than sixteen miles below Galisteo. There the rocks dip toward the east-northeast and at a low angle; this is the northern termination of an extensive area of Laramie, reaching southward for many miles and surrounding the Placer and Sandia mountains. The eastern outcrop of the Laramie beds passes rudely north and south through Galisteo, and there the dip is westward. The width of the area from east to west along the creek is not far from fifteen miles.

A detailed section of 440 feet, taken on the western outcrop, bears no resemblance in detail to sections from the same horizon in the Trinidad coal field, and correlation of the beds in the two fields is not possible. The coal beds in the Galisteo area are thin and variable, and little of economic interest exists aside from the anthracite beds, which contain coal altered by the influence of a gigantic dike passing between the Placer mountains and Galisteo creek. But there is much material of scientific interest, for the Laramie beds show an unexpected intimacy with the underlying Fort Pierre.

Passing the eastern outcrop of the Laramie, one comes at once to a wide park, lying mostly on the south side of the Arroyo San Cristobal and eroded amid the Colorado shales. The Fort Pierre sub-group occupies the western side of this park and, as usual, is much thicker than are the Niobrara and Fort Benton combined. Its shales show the ordinary features, for here are the lines of huge ferruginous concretions, of calcareous concretions, and the succession of dark, gray and yellow shales with abundance of selenite crystals. The concretions, except where showing a cone-in-cone structure, are full of fossils; enormous *Inocerami* with smaller species are common, *Ammonites*, *Baculites*, *Tachytriton*, *Aporrhais*, *Gyrodes*, *Fasciolaria* and *Ostrea* are abundant, all of them belonging to species occurring in the Fort Pierre group at other localities farther north.

Below the Fort Pierre are the bluish-gray argillaceous limestones of the Niobrara sub-group (Cretaceous No. 3) with the same physical features everywhere shown throughout the whole region south from Denver, and containing *Inoceramus problematicus* along with other species always regarded as characterizing this horizon. The exposures of this group are few but ample. An excellent exhibition can be seen at barely a mile southeast from Galisteo, where the limestone was quarried to be burned into lime. The dark brown shales of the Fort Benton (Cretaceous No. 2) are ill-exposed at the base of the Dakota mesa, which forms the eastern boundary of the park, south from the Arroyo.

The Dakota is well exposed, the three provisional groups, which will be proposed in my report, being shown along the Arroyo San Cristobal. The Upper Dakota forms the mesa or east wall of the park and consists of light gray and yellow sandstones; the Middle Dakota consists of blue, white and red sandy to clayey shales, with a bed of limestone, a conglomerate of limestone and iron ore and streaks of gypsum; while the Lower Dakota, made up of gray and yellow sandstones like those of the Upper Dakota, reaches eastward and becomes the upper part of a great mesa, the southwest wall of the Pecos valley.

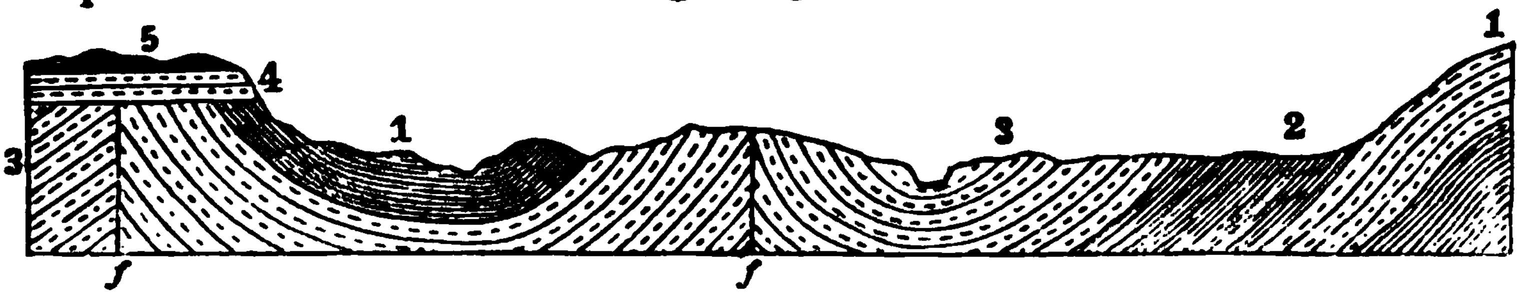
The succession in the lower Galisteo area is absolutely clear, showing the Dakota, Fort Benton, Niobrara, Fort Pierre and Laramie groups in their proper order. All of these dip westward until perhaps eight miles below Galisteo, where the dip is reversed so that the Laramie beds run out at sixteen miles below Galisteo and the Fort Pierre shales come again to the surface. Each of these groups is perfectly characterized and no difficulty is encountered in the attempt to identify them. The physical features and the fossils are not materially different from those found elsewhere in the same groups within the

whole region south from Denver, except that *Halymenites major*, so common at the base of the Laramie group in the Trinidad coal field, is absent here. But impressions of dicotyledonous plants occur in the Galisteo region, which are closely allied to those found in the Trinidad coal field. The coal beds on the northeast slope of the Placer mountains are as clearly Laramie as are those of the Trinidad or the Cañon City coal field.

But the geology of the upper Galisteo area is far from being so simple as that observed along the south side of the creek within the lower area.

No reference has been made to the north side of the creek within the lower area; that can be considered more conveniently in connection with the upper area. A broad uneven park, designated on the Engineer map as the Arroyo de Los Angeles, opens into the lower area at perhaps five miles below Galisteo, and the dike, previously referred to, forms its southeast boundary for several miles.

If a section be carried across the area of the upper Galisteo near its southern edge, the conditions will be found such as are represented in the following diagram.



CROSS SECTION ON THE UPPER GALISTEO.

1. Dakota. 2. Colorado. 3. Laramie. 4. Galisteo. 5. Alluvium.

The Upper Dakota sandstone is in the bluff on the east side, where the dip is very rapid; behind it are the shales and limestones of the Middle Dakota, and the sandstones of the Lower Dakota are shown still further east. Going westward toward Galisteo creek, one crosses the Dakota, the imperfectly exposed Fort Benton and Niobrara, the finely exposed Fort Pierre, and finally before reaching the creek, finds himself on the Laramie sandstones. Thus far the dip has been *westward;* but immediately beyond the creek, the dip is reversed, so that before the low insignificant roll, separating the Arroyo de los Angeles from the Galisteo, is reached, the Laramie rocks are dipping *eastward* and almost vertical, thus forming a synclinal.

But on the opposite side of this low divide, the Lower Dakota sandstones are exposed and dip westward at 65°; at but a little way further westward are the variegated shales and the limestone of the Middle Dakota. On the west side of the Arroyo, the Lower Dakota rocks are dipping very sharply eastward, so that here too a synclinal exists. Thus there are two faults, one following the divide between the Arroyo and the creek, while the other follows the west side of the Arroyo,

whereby this fragment of Dakota has been thrust through the Laramie rocks. The two faults come together on the north side of lower Galisteo at the mouth of the Arroyo and the Dakota rocks do not cross the creek. The Colorado shales do not appear on either side of the faulted area.

But on the west side of this arroyo there appears a series, newer than any yet noticed. It covers the mesa stretching west and north from the Galisteo, and is continuous from the Santa Fe and Placer road on the lower Galisteo almost to the end of the Archean area on the upper Galisteo. This is the Galisteo group. As far as exposed within the area examined, which extends to but a little distance west and north from Galisteo creek, this group is

1. Breccia of trachyte...... 150 feet.
2. Soft, light gray sandstone.. 40 feet.

The breccia is well shown on the lower Galisteo from the Santa Fe and Old Placer road to the mouth of the Arroyo de los Angeles. It is exceedingly dark gray or even lead-colored and is composed altogether, where examined, of trachyte in angular fragments, cemented by finer material apparently of similar nature. This breccia was followed up the Arroyo to the Galisteo and Santa Fe road; but there it practically ends, and the evidence suggests that it was worn away by the erosion which produced the broad mesa. Its fragments litter the surface of that mesa. The thickness assigned this mass is that seen at the mouth of the Arroyo. It may be greater further toward the northwest.

The sandstone is very light gray, excessively soft and incoherent, so that it yields as readily to the weather as though it were loose sand, weathering indeed more freely than do the tough alluvial deposits along the creeks. This is the lowest bed of the group found within the area visited.

The relation of the Galisteo group to the underlying rocks is well shown at the head of the Arroyo, where the Dakota beds dip westward at 65°, while the lower sandstone of the Galisteo rests on their planed-off edges and dips in the same direction at less than one degree. A more curious illustration of the unconformability is shown immediately below the mouth of the Arroyo, where the breccia was deposited around a projecting wall of lower Dakota, which dips at nearly 60°; and the contrast in color is as great as that would be between a trachyte dike and a surrounding mass of basalt. Both the breccia and the underlying sandstone are exposed here and are conformable.

The Galisteo beds are not affected by the faults found in the Arroyo de los Angeles, whereas the Laramie beds are involved in them; the breccia is composed largely of trachyte from Los Cerillos, a group of hills, relics of dikes, shown on the north side of Galisteo creek at sixteen miles below the village. But

the outburst of trachyte, forming those hills, caused frightful distortion of the Laramie beds. It is clear, then, that the Galisteo group can not be conformable to the Laramie. The former group does not cross the Galisteo creek at any point.

The lower sandstone of the Galisteo group was followed up the creek for more than seven miles above Galisteo, and its ashen color gives a strange appearance to the deeply eroded face of the mesa. The vertical yellow and almost white sandstones of the Lower Dakota yield readily to the weather and the debris from the light gray Galisteo sandstone mingles with that from these; so that, to one ascending the creek and following the line of the eastern fault, the Galisteo sandstone seems to be triple, white, yellow and gray, whereas the white and yellow belong to the Lower Dakota, on which the Galisteo sandstone rests unconformably.

The coal beds of the Placer mountains, occupying the plateau between those mountains and Galisteo creek are synchronous with those of the Trinidad coal field and belong to what is known as the Laramie group, which, however, is synonymous, in part at least, with Fox Hills.

The Galisteo group rests unconformably on the Laramie and Dakota; and contains a great bed composed wholly of the later lavas; it is therefore Tertiary.

ART. LIX.—*Short Notes upon the Geology of Catoosa County, Georgia;* by A. W. Vogdes, U. S. Army.

A SHORT distance west of Catoosa Station, on the Western and Atlantic Railroad, we find a small cut which exposes the rocks of the Niagara period. This formation is composed in descending of the following strata:

1. Thin bed of limestone made up of crinoidal joints.
2. Cherty bed containing the columns of *Caryocrinus.*
3. Shaley beds with concretions.
4. Black slate containing about fifty per cent of bituminous matter.

This outcrop in the valley of the Chickamauga is not over ten feet in thickness and dips about twenty-five degrees to the east. A few hundred yards to the west along the river bank, the topography of the country becomes more hilly, and the railroad passes through a cut of about 100 feet. On the map of the county this is known as section 28, lot no. 204, or Taylor's Ridge. This section exposes an outcropping formation of the Upper Silurian Age which belongs to the Clinton

Epoch. The upper beds are thin and composed of an arenaceous limestone, containing fragments of Crinoids and shells more or less wave-broken, as if this stratum marked the line of the Clinton sea. Immediately beneath the limestone we find a laminated sandy bed intermixed with sandstone of different degrees of hardness, which is well exposed in the railroad cut and along the banks of the Chickamauga River. The total thickness of these beds is about 150 feet, the strata having a general dip 15° east.

The geological formation of Taylor's Ridge is more clearly defined with regard to the Upper Silurian age about ten miles southeast from Catoosa station, at Dug Gap in Whitfield county. This section exhibits the Lower Silurian black shales outcropping along the base of the gap, dipping about twenty-five degrees to the east, and known in Dalton as the "coal beds;" immediately above these shales the Medina sandstones appear or a sandstone which stratigraphically may be assigned to this group; as far as examined it contains no fossils. Superimposed upon these sandstones along the second bench of the Gap we find the Clinton, which is composed in descending order of the following strata:

1. Arenaceous layers and sandstone.
2. Hematitic layers containing *Calymene Clintoni*, *C. rostrata*, and generally trilobitic.
3. Arenaceous shales.
4. Sandstone containing *Streptorhynchus subplana.*
5. Hard sandstone containing hematite.
6. Light sandy beds of the Medina.

The best section examined is about twenty feet in thickness, but the measured thickness of the Clinton gives about 150 feet.

In order to illustrate the true geological sequence of Taylor's Ridge it is necessary to trace the different rocks from Atlanta to Ringgold, but at present we will simply give the section at Ringgold, which is about four miles to the west of our first section, taken near Catoosa station. The town of Ringgold is located in a valley composed of the Trenton limestone. This group is highly fossiliferous; it has a northwest and southeast strike, dips fifteen degrees to the east, being composed of a flinty rock, underlaid by a chocolate-colored shale, which is generally denuded; these shales are underlaid by a blue limestone of over three hundred feet in thickness. Superimposed and forming the hills is a great mass of red laminated sandstone of the Hudson River group. These sandstones are about five hundred feet in thickness, dip nineteen degrees east, one mile east of Ringgold in the gap, and contain only a few specimens of *Orthis testudinaria.*

Between Ringgold and Catoosa Station the Chickamauga river divides the ridge; the hills to the northwest are called Oak Mountains, and those on the southeast Taylor's Ridge. After passing through this gap the eastern exposure of these hills shows the overlying Medina, Clinton and Niagara groups.

The paleontological characteristics of this outcropping stratum of the Upper Silurian periods are interesting, especially the fossils of the upper beds. These fossils are poorly preserved and consist generally of casts. From our collection we have been enabled to indentify the following species:

Calymene Clintoni Hall; *Cryptonymus* (*Encrinurns*) *ornatus* Hall and Whitfield; *Cryptonymus* (*Encrinurus*), *Illænus*, *Proetus; Leperditia*, sp., having the right valve marginated by a furrow, except along the dorsal edge, as in *L. marginata; Othis elegantulo*, a species common to the Clinton and Niagara group; *Chætetes lycoperdon*, cast from the lower beds; *Zaphrentis bilateralis?*, broken specimens from the upper bed; *Conularia*, sp.?

Of the *Cryptonymus ornatus* we have in our collection two pygidia which we have assigned to this species, although the casts do not show the nodes ornamenting the axis and pleuræ. The specimens compare otherwise with Professor Hall's type given in Palæontology of New York, vol. ii, pl. lxvi*a*, fig. 1*a*. Vertical distribution Clinton group.

There is also a new trilobite, *Calymene rostrata* Vodges, from the upper arenaceous limestone beds of the Clinton group, Catoosa Station, Georgia, which will be fully described hereafter. It differs from all other species of this genus in having a distinct projecting process in front of the glabella. The facial lines cut the anterior border at the apex, giving to the frontal limb a triangular form; at their juncture the marginal border is raised and forms the triangular process which supports the projection.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On Electrolysis with Alternating Currents.*—Supposing that certain chemical transformations in the living organism are due, not to reduction or oxidation alone, but to both combined, Drechsel has devised a method for subjecting a liquid to reduction and oxidation in rapidly alternating succession. For this purpose, the electrodes of a Grove battery of 4 to 6 cells are placed in the solution, an automatic commutator being included in the circuit, so as to reverse the current rapidly. Each electrode thus becomes alternately positive and negative, first oxygen and then hydrogen being alternately evolved on its surface in the nascent state, each exerting its special action upon the dissolved substance. The

first solution experimented with was one of ammonium carbonate, the same as is used as a reagent. The electrodes were of platinum. Gas was actively evolved, the temperature rose, and after eight hours the experiment was interrupted and the liquid was evaporated on the water bath. From it a salt crystallized out in beautiful white needles. On analysis it was found to contain 64·69 per cent of platinum and was evidently a salt of a platinum base. The small quantity prevented complete investigation; though its solution gave with concentrated hydrochloric acid a bright green and with nitric acid a sky-blue crystalline precipitate. The electrodes lost in ten hours 0·1 gram; while when the electrolysis was conducted with a continuous current in the ordinary way, no platinum at all could be detected in the solution and at most only 0·002 gram had been transported from the anode to the cathode. On repeating the experiment with a less rapid alternation of the current, the liquid became warm, but gave no precipitate; on cooling it, however, during the experiment, an abundant crystalline precipitate was formed, which though also a salt of a platinum base, contained only 38·6 per cent of platinum, and gave with hydrochloric acid, not a green but a colorless crystalline powder consisting of microscopic needles. Finally, a solution of grape sugar mixed with sodium phosphate was submitted to alternating electrolysis, using platinum electrodes of large size, contact being prevented by a disk of filter paper between them. At the close of the experiment, there was formed on the platinum, at the place where the paper had rested against it, a brownish, transparent crust, easily separated into plates, and which left on combustion a considerable amount of platinum. The author is continuing his experiments upon this new method.

In a note to this paper, KOLBE says that the highly interesting observations of Drechsel raise the question of the behavior of salts and salt-solutions of inorganic and organic acids in presence of powerful and alternating voltaic currents; as, for example, whether an aqueous solution of potassium acetate suffers decomposition without accompanying oxidation. Since Drechsel does not purpose to extend his studies in this direction, Kolbe intends to examine the action of a series of salts under these conditions.—*J. pr. Ch.*, xx, 378, Oct., 1879. G. F. B.

2. *On the Basicity of Dithionic or Hyposulphuric Acid.*—It has been generally assumed that hyposulphuric acid is dibasic and hence that its formula is $H_2S_2O_6$. KOLBE has written it in his Lehrbuch $\left\{ \begin{matrix} SO_2OH \\ SO_2OH \end{matrix} \right.$ or di-sulphoxyl, as oxalic acid is $\left\{ \begin{matrix} COOH \\ COOH \end{matrix} \right.$ or di-carboxyl. If this view be true, hyposulphuric acid should form, not only normal salts, but also acid, and mixed salts. Kolbe has set several of his students at work to endeavor to form either an acid salt or a mixed salt, an ether acid or an amic acid, of hyposulphuric acid, but without effect. Since all these bodies are readily given by oxalic acid, Kolbe comes to the conclusion that hyposulphuric acid is monobasic and contains but one hydroxyl

group. Hence the formula of it should be HSO_3 or $(SO_2)OH$. The importance of this conclusion lies in this, that, if it be conceded, the equivalence of sulphur is five in this compound and it becomes a perissad instead of an artiad as it is in all other combinations.—*J. pr. Ch.*, xix, 485, June, 1879. G. F. B.

3. *On the Non-existence of Pentathionic acid.*—In the hope of converting the polythionic acids into a new series of sulphur acids poorer in oxygen, SPRING submitted them to the action of sodium amalgam. But instead of the result expected a very different one was obtained. The sodium inserted itself between the sulphur atoms, splitting the molecule into two simpler ones; just as oxalic acid is converted by hydrogen into formic acid. For example, with tetrathionate, $KO_3SS.SSO_3K+Na_2=KO_3SSNa+NaSSO_3K$; with trithionate, $KO_3S.SSO_3K+Na_2=KO_3SNa+NaSSO_3K$; with dithionate $KO_3S.SO_3K+Na_2=KO_3SNa+NaSO_3K$. Precisely as $HO_2C.CO_2H+H_2=HO_2C.H+H.CO_2H$. In order to test this reaction in the case of pentathionic acid, the author attempted the preparation of this body; but after five months of work he was unable to obtain it. This result raised the question of the existence of this acid. All attempts to prepare it, by the method either of Wackenroder or of Fordos and Gelis resulted only in the production of tetrathionic acid. The action of hydrogen sulphide upon sulphurous oxide in aqueous solution produces hyposulphurous acid; and this is oxidized as it is formed into tetrathionic acid by the sulphurous acid present, the hydrosulphurous acid of Schutzenberger being formed at the same time. Pentathionic acid, therefore, appears to be as yet unknown.—*Liebig's Ann.*, ccxcix, 97, Oct., 1879. G. F. B.

4. *On the Atomic Weight of Tellurium.*—WILLS has undertaken a re-determination of the atomic weight of tellurium, in order to ascertain whether the value of this constant as at present accepted from the experiments of Berzelius and von Hauer, or the value assumed for it in Mendelejeff's classification, is the more correct. The crude tellurium was purified by fusion with sodium carbonate and sulphur, the fusion extracted with boiling water, the filtrate acidulated with acetic acid, the precipitate well washed, oxidized with nitric acid, evaporated to dryness, heated with hydrochloric acid, the tellurium precipitated by sodium sulphite, washed, dried, fused with potassium cyanide, the fusion treated with water and the deep-claret solution exposed to the air in a flask when the tellurium separates in long needle-shaped crystals. After washing and careful drying these were distilled in a current of hydrogen. The distilled water, nitric and hydrochloric acid used were carefully purified and the accuracy of the weights and balance employed verified. On oxidizing the tellurium with nitric acid, and calculating the atomic weight from the TeO_2 obtained, the mean of five experiments gave 127·8 with a probable error of 0·32. Four experiments on oxidation with equa regia gave 127·907 with a probable error of 0·053. Five determinations by von Hauer's method, of the bromine in the compound K_2TeBr_6, gave Te =

126·83 with a probable error of 0·198. Hence the atomic weight of tellurium is essentially that obtained by Berzelius and von Hauer, and is higher than that of iodine, after which in Mendelejeff's system it should be placed, instead of between iodine and antimony.—*J. Ch. Soc.*, xxxv, 704, Oct., 1879. G. F. B.

5. *On the Preparation of Propylene glycol from Glycerin.*—A very convenient method has been proposed by BELOHOUBEK, for the direct preparation of propylene-glycol from glycerin. When glycerin is mixed with sodium amalgam in the proportion of one molecule of glycerine to one atom of sodium, and gradually warmed, a gummy mass results which, according to Letts, consists chiefly of monosodium glycerate. On submitting this to distillation, water and gas are at first evolved, then there comes over a colorless liquid readily miscible with water, and a brown strongly smelling liquid, lighter than water. The colorless liquid fractionated gave a product boiling at 186°–188°, having a weak odor like allyl, a burning taste, removable by agitation with ether, and on analysis the formula of propylene glycol. Its specific gravity at 0° C., was 1·054, its vapor density 2·68. With hydrochloric acid, it formed a chlorhydrin, which by the action of caustic potash gave propylene oxide. The yield was about 16 per cent of that required by theory. That the action here is due to the sodium of hydrate formed, was proved by distilling equal molecules sodium hydrate and glycerin. Nine per cent of the theoretical yield was obtained.—*Ber. Berl. Chem. Ges.*, xii, 1872, Oct., 1879. G. F. B.

6. *On Skatol.*—In his researches on the volatile substances contained in human feces, BRIEGER isolated a series of bodies belonging, some to the fatty and others to the aromatic class. The principal aromatic product of the decomposition of albumen in the intestinal canal, is a substance resembling indol to which he has assigned the name skatol. It crystallizes in brilliant white plates and posesses an intense fecal odor. It fuses at 93·5°, and is difficultly soluble in water. Warmed with dilute hydrochloric or nitric acid, it gives a violet color. Analysis gives it the formula C_9H_9N, its vapor density being 65·2. Blood-albumen, digested with pancreas and water at 36° C. for six to ten days, yields skatol on distillation. Two and a half kilograms albumen gave one gram of skatol.—*Ber. Berl. Chem. Ges.*, xii, 1985, Oct., 1879. G. F. B.

7. *On the Synthesis of Lactose.*—DEMOLE has succeeded in effecting a partial synthesis of milk-sugar, accomplishing an important step toward its complete synthetical production. Starting from the octacetyl-diglucose of Schutzenberger, which is isomeric and not identical with octacetyl-saccharose, the author, assuming that the glucose molecules of both saccharose and lactose are different, sought, by combining levulose and dextrose to produce saccharose and by uniting galactose with lactoglucose to produce lactose. Comparing octacetyl-diglucose with octacetyl-saccharose, they were found to have some points of difference, in solubility,

in rotatory power, and in their reactions, the former yielding di-glucose, the latter cane-sugar. By the action of dilute acids upon lactose, two isomeric bodies, galactose and lactoglucose are produced. After removal of the acid, the product of this reaction was evaporated and carefully dried. It had all the properties of a mixture. It was mixed with three parts of acetic oxide, and heated to boiling until complete solution resulted. On treatment with water, a gelatinous ether resulted having the properties of octacetyl-lactose. On saponification by pouring the alcoholic solution of the synthesized ether into baryta water at 90°, and heating, there was obtained, on neutralizing and evaporating to dryness, and recrystallizing, a substance having all the properties of lactose, crystallizing in the orthorhombic system, and having a rotation $(\alpha)_D = +56{\cdot}7°$. On heating to 140°–145°, it afforded an anhydride.—*Ber. Berl. Chem. Ges.*, xii, 1935, Oct., 1879.

G. F. B.

II. Geology and Natural History.

1. *Report of the Geological Survey of Canada*, for 1877–78, Alfred R. C. Selwyn, Director. 8vo. Montreal, 1879. (Dawson Brothers).—This volume contains a wide range of geological observations, and is a very valuable contribution to the science. It includes a Report on the Quebec group by Mr. Selwyn; on Southern British Columbia (173 pages) by G. M. Dawson; with an Appendix on the Fossil Insects, by S. H. Scudder, and on Tertiary plants, by Dr. Dawson; on the East coast of Hudson Bay, and on the country between this Bay and Lake Winnepeg, by R. Bell; on New Brunswick Geology, by R. W. Ells, L. W. Bailey, and G. F. Mathew; on Cape Breton, N. S., by H. Fletcher; on minerals of the Apatite-bearing veins of Ottawa, with notes on miscellaneous rocks and minerals, by B. J. Harrington; on Canadian Apatite, by C. Hoffmann; and is illustrated by many sketches, sections and maps.

Mr. Selwyn divides the Quebec series of Logan into three groups: "(1.) The Lower Silurian group," containing fossils; "(2.) The Volcanic group, probably Lower Cambrian." "(3.) The Crystalline Schist group (Huronian ?)." The evidence of a general volcanic origin of the second group is not stated. The kinds of rocks mentioned:—"thick-bedded feldspathic, chloritic, epidotic and quartzose sandstones, red, gray and greenish siliceous slates and argillites, great masses of dioritic, epidotic and serpentinous breccias and agglomerates, diorites, dolerites, and amygdaloids holding copper ores, serpentinous felsites, and some fine-grained granitic and gneissic rocks, also crystalline dolomites and calcites," make a remarkable assemblage to be spoken of as "these volcanic rocks." They were, for the most part, included in the Sillery sandstone formation by Logan. The account of the Quebec group is followed by the statement that, "in view of the usual associations of Labrador feldspars," (referring here to their

occurring as a constituent of some igneous rocks) "the labradorite or anorthosite" rocks of the Adirondacks and British America, probably "represent the *volcanic* and intrusive rocks of the Laurentian period."

These conclusions as to volcanic rocks make the mineral labradorite, and some others, settle a great question that should be settled by geological investigation; for we rightly ask that volcanic origin should be proved by the presence of obvious volcanic or eruptive conditions. What there is in a lime-and-soda feldspar to make its presence proof of eruptive origin, or of the existence of great volcanoes in a region that shows no other evidence of it, no one has pointed out. Lime is an exceedingly common material in sediments; and soda or sodium is present in other feldspars, and, in the state of chloride, abounds in sea water and occurs in salines and beds of rock-salt in strata of various ages. Moreover, the mineral labradorite, certainly does occur as a chief constituent in some metamorphic rocks that have nothing of volcanic origin in their constitution, as the writer has shown to be true in the vicinity of New Haven, Connecticut. So with felsyte, a rock made up of common feldspar or orthoclase, with often quartz--its composition is not sufficient evidence of an igneous or volcanic-ash origin.

Announcements on such evidence, of the former existence of volcanoes in a region, belong, in the writer's view, only to fancy-sketches.

The rocks of Mr. Selwyn's volcanic series were, for the most part, pronounced metamorphic by Logan, one of the best of geologists; and the list above given seems to show that Logan was, in all probability, right in this respect, whatever may be the fact as to the relative position of the Sillery sandstone and the fossiliferous beds of the Quebec group. The facts afforded by the Green Mountain region to the south in Vermont and Massachusetts, brought out by Mr. Wing and the writer, bear on the latter question.

In the course of Mr. Selwyn's paper on the Quebec group, he makes the just remark: that the names Norian, Montalban, Taconian and Keweenian, "applied to pre-Cambrian formations," serve no useful purpose; these representing "simply groups of strata which occupy the same geological interval and present no greater differences in their physical and mineralogical characters than are commonly observed to occur in formations of the same epoch in widely separated regions." "No better instances of such difference could be cited than the Mesozoic and Carboniferous formations of British Columbia, and those of the same periods in Eastern America and the Silurian and Cambrian formations of Australia, Europe and America."

Mr. G. M. Dawson's report contains a large amount of important information, both geological and economical. With regard to the drift of the interior of Columbia, he says that glacial markings occur up to a height of 5,280 feet on Iron Mountain; that, in the early part of the Glacial era, a great glacier, confluent

with that of the coast, covered probably the interior of the Province, which may have been 2,000 feet thick; that the regions of greatest precipitation and height of the ice was north of the 54th parallel; that it is "highly probable" that that part of the Pacific coast stood at an elevation greater than at present in times immediately preceding the Glacial, and "may have retained this altitude" during the era of the great confluent glacier. He adds, with an expressed questioning, "If I am right in attributing the flooding of the interior to the sea, we find a rapid subsidence of the land coincident with the decay of these vast glaciers;" and then speaks of a *second* short advance of the glaciers on the plateau from the mountains. No evidence of the presence of the sea in fossils or other decisive facts is presented.

Mr. R. Bell states, that on the east coast of Hudson Bay there is "abundant evidence that the sea-level is falling at a comparatively rapid rate;" that since the Posts of the Hudson Bay Company were established at the mouths of the various rivers, there has been an increasing difficulty in approaching them with large craft; that it amounts probably to between 5 and 10 feet a century. Mr. Bell states that this sinking is apparent also on the west coast of the bay at the mouth of the Nelson and Haye's Rivers; that an island, "Mile Lands," now several feet above high tide, was, "within the recollection of the generation preceding the present one, submerged at high tide." About the beginning of the present century vessels ventured in Ten-shilling Creek, which could not now approach its mouth. To the north of Lake Winnipeg, a region of lakes, the glacial scratches in general run southwestward, and the direction is mostly between S. 35° W. and S. 55° W.

The reports on New Brunswick have great interest from the relation of the rocks to those of Maine, and Mr. Mathew's, on the superficial geology of the Province, gives long lists of courses of glacial striæ, as well as other information respecting the Quaternary. These, and the following reports, contain much that would be cited here if space allowed. J. D. D.

2. *The Geological and Natural History Survey of Minnesota*, under N. H. Winchell, State Geologist. *7th Annual Report for the year* 1878. 123 pages, 8vo. Minneapolis, 1879.—The report contains a statement as to the work of the year, made brief in accordance with the action of the Board of Regents, which has ordered also that the survey be substantially completed in four years, and be followed by the publication of a Final Report of two volumes, one on the Northern part of the State, and the other on the Southern. The chief part of the volume is occupied with a paper by C. L. Herrick, on the Entomostraca of the State, which is illustrated by 20 plates. The writer recommended the publication of this paper as the report states; but he does not vouch for the correct determination of all the species. J. D. D.

3. *Brief Notices of some recently described Minerals.—Eggonite.* Observed by Schrauf in minute crystals, of a light brown color,

implanted upon crystals of calamine from Altenberg, near Aachen. The crystals bear some resemblance to certain simple forms of barite, but are in fact triclinic, though with a pseudo-monoclinic symmetry due to twinning. H.=4–5. In composition probably a silicate containing cadmium.—(*Zeitsch. Kryst.*, iii, 352).

Herrengrundite. Described by Brezina as a basic copper sulphate. It occurs in six-sided tabular crystals, belonging to the monoclinic (or triclinic) system, with perfect basal cleavage. H. = 2·5. Color dark emerald green. Associated with gypsum, malachite and calcite from Herrengrund (Urvölgy), Hungary (Zeitsch. Kryst., iii, 359). The same mineral was described about the same time by Szabó (Tsch. Min. Mitth., ii, 311) under the name Urvölgyite. He differs from Brezina in making the lime afforded by the analysis an essential coustitutent of the mineral, while the latter regarded it as being due to the presence of gypsum.

Hofmannite. Occurs in colorless, tasteless, tabular crystals in lignite. Composition given by the formula $C_{20}H_{36}O$. Described by Bechi (Pisa).

Leucomanganite. A foliated and radiated snow-white mineral. Colorless in thin plates, but before the blowpipe becomes brownish-black and fuses easily. Chemical composition unknown; contains protoxides of iron and manganese, alkalies and water.—(*Sandberger, Jahrb. Min.*, 1879, 370.)

Louisite. A leek-green, translucent, vitreous mineral; brittle with splintery fracture. H. = 6·5. G. = 2·41. Gelatinizes in hydrochloric acid. An analysis by H. Louis afforded:

SiO_2	Al_2O_3	FeO	MnO	CaO	MgO	Na_2O	K_2O	H_2O
63·74	0·57	1·25	tr	17·27	0·38	0·08	3·38	12·96=99·63

From Blomidon, N. S.; named by D. Honeyman.

Reinite. A blackish-brown, opaque mineral, with sub-metallic luster. Observed in large crystals belonging to the tetragonal system. The composition is expressed by the formula $FeWO_4$. Discovered by Professor Rein in Kimbosan in Kei, Japan, named by K. v. Fritsch and described by Luedecke.—(*Jahrb. Min.*, 1879, 286.)

Plagiocitrite, Clinophæite, Wattevillite, Clinocrocite: Hydrous sulphates described by S. Singer as being identified by him at the Bauersberg, near Bischofsheim.

Bhreckite (Vreckite), *Xantholite, Abriachanite:* Names given provisionally by Heddle to substances "which may prove to be new Scottish minerals." Bhreckite is a chlorite-like mineral; xantholite has nearly the composition of staurolite, but is thought to be monoclinic in crystallization; abriachanite is an impure, bluish clay-like mineral.—(*Min. Mag.*, iii, 57, 1879.)

Haughtonite is, according to Heddle, a new mica. It has a jet black color, in thin plates transmitting a dark brown light. G. = 3·03. An analysis of material from hornblendic gneiss of Roneval afforded:

SiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	H_2O
37·16	15·01	7·69	17·35	1·04	8·88	1·13	1·60	8·18	2·12=100·16

Analyses of a similar mica from other localities afforded results agreeing more or less closely with the above. Its claim for recognition as a species distinct from biotite and lepidomelane rests chiefly upon the relative proportion of the two oxides of iron.

4. *Ueber den Boracit* von H. BAUMHAUER.—Through an investigation of the etching figures produced on crystals of boracite by a dilute mixture of hydrochloric and sulphuric acids, Baumhauer has proved that the species belongs to the orthorhombic system. This conclusion was earlier reached by Mallard, but Baumhauer explains the occurring forms by a somewhat different and more simple method of twinning. The method of investigation employed is one which he has done much to develop, and which he has successfully applied to the solution of other similar problems.—(*Zeitsch. Kryst.*, iii, 337.)

5. *Genaue Messungen der Epidot-Krystalle aus der Knappenwand im oberen Sulzbachthal* von N. VON KOKSCHAROW, Sohn.—The already very extensive series of monographs devoted to the crystallization of epidote has been recently enlarged by an important memoir by N. von Kokscharow, the son of the great Russian mineralogist. This memoir contains the result of a large amount of careful work, including the measurement and calculation of the important angles of the occurring forms. The axial ratio and angle of inclination for the species are determined with a high degree of exactness that leaves nothing to be desired.

6. *Canadian Apatite;* by CHRISTIAN HOFFMANN (Geological Survey of Canada).—Mr. Hoffmann has analyzed a series of Canadian apatites; he shows that they all belong to the class of fluor-apatites containing but a very small amount of chlorine. They are in general very free from impurity, as oxide of iron.

7. *Eucalyptographia: A Descriptive Atlas of the Eucalypts of Australia and the adjoining Islands;* by Baron FERDINAND VON MUELLER, K.C.M.G., F.R.S., etc. Decades 1 and 2, 4to, 1879. Melbourne and London. (Trübner, &c.).—It was a happy thought of the noted Australian botanist to describe anew and illustrate the species of *Eucalyptus*,—a thought long entertained, we are told, and at length undertaken under the patronage of the Victorian Government, and under conditions which promise success. For, in a country in which trees are of inestimable value, this genus comprises the principal timber-vegetation and is rich in other industrial products, while the species are very numerous, of very different economical importance and use, and almost throughout they are of difficult botanical limitation. Then Eucalyptus-trees are the sole rivals of the *Sequoias* of California in grandeur, appear in some cases to surpass them in height, and certainly exceed them in rapidity of growth. For the task in hand, even if economical considerations alone are taken into account, the indefatigable editor will certainly need, and ought freely to command, all the aids which can be afforded; but he complains, in the preface, that indispensable auxiliaries which he formerly controlled, have been withdrawn from the Government Botanist's department.

The complaint has reference to laboratory accommodation for technological investigation, and to the author's separation from the Botanic Garden, containing a large collection of growing trees which he had laboriously brought together. *Per contra*, let him consider how much valuable time he saves for true botanical work by his riddance from the multifarious cares which garden-superintendence involves.

In a work of this kind, which must needs take several years to finish, during which new species are sure to be discovered, and new information respecting the old ones is sure to come to light, the only practicable course is to bring out the illustrations without regard to scientific order, leaving them to be collected and systematically arranged at the completion of the undertaking. Consequently the figures and the letter-press are neither paged nor numbered. Both are in quarto form, a leaf (and commonly the whole of its two pages), as also a well-filled plate, being devoted to each species. The plates are well drawn, executed in good lithography, and contain fair dissections and not a little of microscopical detail. Some extra plates are given in illustration of the structure of the wood, and also of the anthers. To figure all the *Eucalypti* will require fourteen or fifteen decades; even then the work will be comparatively low-priced, for the decades are published at five shillings each. The book will have an interest beyond Australia, in all climates in which the cultivation of these trees may be hopefully attempted, such, for instance, as the south-western part of California. Indeed the mountain species might be tried on any part of our western coast, and some might be expected to withstand the occasionally severe cold of the districts bordering the Gulf of Mexico. A. G.

8. *Monographiæ Phanerogamarum Prodromi, nunc Continuatio, nunc Revisio* auctoribus ALPHONSO et CASIMIR DECANDOLLE. Vol. II, *Araceæ* auctore ENGLER. Paris: Masson, Sept., 1879. pp. 681.—This second volume of the supplement to the Prodromus is completely occupied by Dr. A. Engler, now Professor at Kiel, with his monograph of the order *Araceæ*. This great order Engler accepts in the largest sense, including the "*Pistioideæ*" (of *Pistia* only reduced to a single species), and the "*Lemnoideæ*" (*Spirodela*, *Lemna*, and *Wolffia*), these being ranked as the ninth and tenth sub-families of the order. The larger of the other sub-families divide into tribes and sub-tribes, and the genera are one hundred and one! A condensed account of the structure, distribution, and taxonomy of Araceous plants precedes the systematic portion, and a full index follows. There are no figures; but the author has illustrated the Brazilian species in the Flora Brasiliensis, and the structure and classification in the Acta of the Acad. Nat. Curiosorum. The genera and species of *Lemnaceæ* or *Lemneæ* (names surely to be preferred to "*Lemnoideæ*") are omitted, being the subject of a recent monograph by Hegelmaier. Under the habitat the country is cited, and then the specimens which have come under the author's observation, with their source. A. G.

9. *Anatomie Comparée des Feuilles chez quelques Familles de Dicotylédones;* par M. CASIMIR DECONDOLLE. A memoir separately issued from the *Mem. Soc. Phys.* and *Hist. Nat. de Genève*, tome xxvii, partie 2. 1879. pp. 427–480, and two plates, 4to.—One of Cassimir DeCandolle's earliest studies was into the structure and relations of the fibro-vascular elements of the leaf, and the results and deductions were brought out in his brief article entitled Theorie de la Feuille, in the year 1858. The present paper is in no respect theoretical, nor does it investigate the minute anatomy and formation of the vascular bundles. But it presents a comparative view of the general structure of the woody system of the petiole and principal veins in a very considerable number of Dicotyledons, mainly trees, and belonging to different natural orders. In this way the nature of the principal differences from species to species, and from one order to another, are brought to view, and the taxonomical value of such characters indicated. It is found that different species of the same genus sometimes accord, but sometimes differ notably in this part of their anatomy. Wherefore the classificatory importance of these differences is low, yet they may often be turned to good account in the discrimination of related species. The essential fibro-vascular system of the petiole, as displayed on a cross-section, forms either a closed ring or an arc open superiorly between the outer or cortical and the inner or medullary tissue; in the first case it is said to be closed or complete, in the second open or incomplete. Very commonly this is the only vascular system of the petiole, ribs, or veins. Not rarely there are additional or accessory bundles, sometimes external to the essential system, or *intracortical;* sometimes within the arc or ring, or *intramedullary;* occasionally there are both intracortical and intramedullary bundles. Generally plants of the same order will agree, at least approximately, in having the closed or open system, and in having or wanting the accessory bundles without or within. But, while *Acer Pseudo-platanus* has a well developed intramedullary cord, *A. platanoides* has none, and in general the Maples are divided in this respect quite independent of other characters; and the difference is similar and equally marked between the species of *Æsculus*. The oaks, which have been made a special study in this regard, appear to be somewhat equally divided between species provided with and those destitute of intramedullary bundles; but related species generally belong to the same category, yet not always. For in one case two species, of doubtful distinction until now, are confirmed by the discovery of an anatomical difference of this sort. All the Birches examined want the intracortical bundles and the principal system forms an open arc, and one or two Alders nearly agree with them; while the others have a closed ring and are furnished with intracortical bundles. The two plates contain about thirty accurately drawn and carefully engraved figures of sections, moderately magnified. A. G.

10. *Bentham and Hooker's Genera Plantarum.*—It is known to Botanists generally that the first part of the third (and concluding)

volume of this important work is passing through the press. We are informed that this part, which will complete the *Dicotyledones*, will be published in London at the close of the year. It is known to many of his correspondents that the present writer has arranged, by taking a considerable number of copies to secure this work for American botanists, or the public libraries with which some of them are connected, at a reduced price. As his own lists of those who have hitherto received the work through his mediation may not be complete, all those who wish to obtain the new part in this way are requested to communicate with him upon the subject without delay. A. G.

11. *Chesapeake Zoological Laboratory; Johns Hopkins University*, Baltimore, Md. *Scientific Results of the Session* of 1878 (June 24th to August 19th.) 170 pp. 8vo, with 13 plates. Baltimore: 1879.—This volume, issued under the auspices of the Johns Hopkins University, contains, besides lists of land plants and animals found at Fort Wool, the following important zoological papers: Development of Lingula, Development of Gasteropods, and Development of Squilla, with 12 plates, by W. K. Brooks; *Lucifer typus*, by W. Faxon, with 1 plate; and Early stages of Amphioxus, by H. J. Rice, with 2 plates.

III. Astronomy.

1. *The Minor Planets, arranged in the order of their numbers;* by Aaron N. Skinner. (Communication to the Editors, dated Naval Observatory, Washington, October 4.)

No.	Name.	Discoverer.	Disc. No.	No.	Name.	Discoverer.	Disc. No.
1	Ceres	Piazzi		20	Massalia	DeGasparis	6
2	Pallas	Olbers	1	21	Lutetia	Goldschmidt	1
3	Juno	Harding		22	Calliope	Hind	7
4	Vesta	Olbers	2	23	Thalia	Hind	8
5	Astræa	Hencke	1	24	Themis	DeGasparis	7
6	Hebe	Hencke	2	25	Phocæa	Chacornac	1
7	Iris	Hind	1	26	Proserpina	Luther	2
8	Flora	Hind	2	27	Euterpe	Hind	9
9	Metis	Graham		28	Bellona	Luther	3
10	Hygeia	DeGasparis	1	29	Amphitrite	Marth	
11	Parthenope	DeGasparis	2	30	Urania	Hind	10
12	Victoria	Hind	3	31	Euphrosyne	Ferguson	1
13	Egeria	DeGasparis	3	32	Pomona	Goldschmidt	2
14	Irene	Hind	4	33	Polyhymnia	Chacornac	2
15	Eunomia	DeGasparis	4	34	Circe	Chacornac	3
16	Psyche	DeGasparis	5	35	Leucothea	Luther	4
17	Thetis	Luther	1	36	Atalante	Goldschmidt	3
18	Melpomene	Hind	5	37	Fides	Luther	5
19	Fortuna	Hind	6	38	Leda	Chacornac	4

No.	Name.	Discoverer.	Disc. No.	No.	Name.	Discoverer.	Disc. No.
39	Lætitia	Chacornac	5	85	Io	Peters	4
40	Harmonia	Goldschmidt	4	86	Semele	Tietjen	
41	Daphne	Goldschmidt	5	87	Sylvia	Pogson	6
42	Isis	Pogson	1	88	Thisbe	Peters	5
43	Ariadne	Pogson	2	89	Julia	Stephan	
44	Nysa	Goldschmidt	6	90	Antiope	Luther	15
45	Eugenia	Goldschmidt	7	91	Aegina	Borrelly	1
46	Hestia	Pogson	3	92	Undina	Peters	6
47	Aglaja	Luther	6	93	Minerva	Watson	2
48	Doris	Goldschmidt	8	94	Aurora	Watson	3
49	Pales	Goldschmidt	9	95	Arethusa	Luther	16
50	Virginia	Ferguson	2	96	Aegle	Coggia	1
51	Nemausa	Laurent		97	Clotho	Tempel	5
52	Europa	Goldschmidt	10	98	Ianthe	Peters	7
53	Calypso	Luther	7	99	Dike	Borrelly	2
54	Alexandra	Goldschmidt	11	100	Hecate	Watson	4
55	Pandora	Searle		101	Helena	Watson	5
56	Melete	Goldschmidt	12	102	Miriam	Peters	8
57	Mnemosyne	Luther	8	103	Hera	Watson	6
58	Concordia	Luther	9	104	Clymene	Watson	7
59	Elpis	Chacornac	6	105	Artemis	Watson	8
60	Echo	Ferguson	3	106	Dione	Watson	9
61	Danaë	Goldschmidt	13	107	Camilla	Pogson	7
62	Erato	Förster		108	Hecuba	Luther	17
63	Ausonia	DeGasparis	8	109	Felicitas	Peters	9
64	Angelina	Tempel	1	110	Lydia	Borrelly	3
65	Cybele	Tempel	2	111	Ate	Peters	10
66	Maja	H. P. Tuttle	1	112	Iphigenia	Peters	11
67	Asia	Pogson	4	113	Amalthea	Luther	18
68	Leto	Luther	10	114	Cassandra	Peters	12
69	Hesperia	Schiaparelli		115	Thyra	Watson	10
70	Panopæa	Goldschmidt	14	116	Sirona	Peters	13
71	Niobe	Luther	11	117	Lomia	Borrelly	4
72	Feronia	C.H.F.Peters	1	118	Peitho	Luther	19
73	Clytia	Tuttle	2	119	Althæa	Watson	11
74	Galatea	Tempel	3	120	Lachesis	Borrelly	5
75	Eurydice	Peters	2	121	Hermione	Watson	12
76	Freia	D'Arrest		122	Gerda	Peters	14
77	Frigga	Peters	3	123	Brunhild	Peters	15
78	Diana	Luther	12	124	Alceste	Peters	16
79	Eurynome	Watson	1	125	Liberatrix	Prosp. Henry	1
80	Sappho	Pogson	5	126	Velleda	Paul Henry	1
81	Terpsichore	Tempel	4	127	Johanna	Prosp. Henry	2
82	Alcmene	Luther	13	128	Nemesis	Watson	13
83	Beatrix	DeGasparis	9	129	Antigone	Peters	17
84	Clio	Luther	14	130	Electra	Peters	18

No.	Name.	Discoverer.	Disc. No.	No.	Name.	Discoverer.	Disc. No.
131	Vala	Peters	19	171	Ophelia	Borrelly	8
132	Aethra	Watson	14	172	Baucis	Borrelly	9
133	Cyrene	Watson	15	173	Ino	Borrelly	10
134	Sophrosyne	Luther	20	174	Phaedra	Watson	20
135	Hertha	Peters	20	175	Andromache	Watson	21
136	Austria	Palisa	1	176	Idunna	Peters	27
137	Meliboea	Palisa	2	177	Irma	Paul Henry	6
138	Tolosa	Perrotin	1	178	Belisana	Palisa	10
139	Juewa	Watson	16	179	Clytemnestra	Watson	22
140	Siwa	Palisa	3	180	Garumna	Perrotin	5
141	Lumen	Paul Henry	2	181	Eucharis	Cottenot	
142	Polana	Palisa	4	182	Elsbeth	Palisa	11
143	Adria	Palisa	5	183	Istria	Palisa	12
144	Vibilia	Peters	21	184	Dejopeia	Palisa	13
145	Adeona	Peters	22	185	Eunike	Peters	28
146	Lucina	Borrelly	6	186	Celuta	Prosp. Henry	7
147	Protogeneia	Schulhof		187	Lamberta	Coggia	2
148	Gallia	Prosp. Henry	3	188	Menippe	Peters	29
149	Medusa	Perrotin	2	189	Phthia	Peters	30
150	Nuwa	Watson	17	190	Ismene	Peters	31
151	Abundantia	Palisa	6	191	Kolga	Peters	32
152	Atala	Paul Henry	3	192	Nausicaä	Palisa	14
153	Hilda	Palisa	7	193	Ambrosia	Coggia	3
154	Bertha	Prosp. Henry	4	194	Prokne	Peters	33
155	Scylla	Palisa	8	195	Eurykleia	Palisa	15
156	Xanthippe	Palisa	9	196	Philomela	Peters	34
157	Dejanira	Borrelly	7	197	Arete	Palisa	16
158	Coronis	Knorre		198	Ampella	Borrelly	11
159	Aemilia	Paul Henry	4	199	Byblis	Peters	35
160	Una	Peters	23	200	Dynamene	Peters	36
161	Athor	Watson	18	201	Penelope	Palisa	17
162	Laurentia	Prosp. Henry	5	202	Chryseïs	Peters	37
163	Erigone	Perrotin	3	203	Pompeia	Peters	38
164	Eva	Paul Henry	5	204		Palisa	18
165	Loreley	Peters	24	205		Palisa	19
166	Rhodope	Peters	25	206	Hersilia	Peters	39
167	Urda	Peters	26	207		Palisa	20
168	Sibylla	Watson	19	208		Palisa	21
169	Zelia	Prosp. Henry	6	209	Dido	Peters	40
170	Maria	Perrotin	4				

ALPHABETICAL INDEX OF THE MINOR PLANETS.

Name.	No.	Name.	No.	Name.	No.	Name.	No.	Name.
ndantia	53	Calypso	79	Eurynome	3	Juno	201	Penelope
ona	107	Camilla	27	Euterpe	191	Kolga	174	Phaedra
ria	114	Cassandra	164	Eva	120	Lachesis	196	Philomela
gina	186	Celuta	109	Felicitas	39	Laetitia	25	Phocæa
gle	1	Ceres	72	Feronia	187	Lamberta	189	Phthia
nilia	202	Chryseïs	37	Fides	162	Laurentia	142	Polana
hra	34	Circe	8	Flora	38	Leda	33	Polyhymnia
aja	84	Clio	19	Fortuna	68	Leto	32	Pomona
este	97	Clotho	76	Freia	35	Leucothea	203	Pompeia
mene	104	Clymene	77	Frigga	125	Liberatrix	194	Prokne
xandra	179	Clytemnestra	74	Galatea	117	Lomia	26	Proserpina
hæa	73	Clytia	148	Gallia	165	Loreley	147	Protogeneia
althea	58	Concordia	180	Garumna	146	Lucina	16	Psyche
brosia	158	Coronis	122	Gerda	141	Lumen	166	Rhodope
pella	65	Cybele	40	Harmonia	21	Lutetia	80	Sappho
phitrite	133	Cyrene	6	Hebe	110	Lydia	155	Scylla
dromache	61	Danaë	100	Hecate	66	Maja	86	Semele
gelina	41	Daphne	108	Hecuba	170	Maria	168	Sibylla
tigone	157	Dejanira	101	Helena	20	Massalia	116	Sirona
tiope	184	Dejopeia	103	Hera	149	Medusa	140	Siwa
te	78	Diana	121	Hermione	137	Meliboea	134	Sophrosyne
thusa	99	Dike	206	Hersilia	56	Melete	87	Sylvia
adne	209	Dido	135	Hertha	18	Melpomene	81	Terpsichore
emis	106	Dione	69	Hesperia	188	Menippe	23	Thalia
a	48	Doris	46	Hestia	9	Metis	24	Themis
ræa	200	Dynamene	153	Hilda	93	Minerva	17	Thetis
la	60	Echo	10	Hygeia	102	Miriam	88	Thisbe
lante	13	Egeria	98	Ianthe	57	Mnemosyne	115	Thyra
	130	Electra	85	Io	192	Nausicaä	138	Tolosa
ıor	59	Elpis	176	Idunna	51	Nemausa	160	Una
rora	182	Elsbeth	173	Ino	128	Nemesis	92	Undina
sonia	62	Erato	112	Iphigenia	71	Niobe	30	Urania
stria	163	Erigone	14	Irene	150	Nuwa	167	Urda
ıcis	181	Eucharis	7	Iris	44	Nysa	131	Vala
trix	45	Eugenia	177	Irma	171	Ophelia	126	Velleda
isana	185	Eunike	42	Isis	49	Pales	4	Vesta
lona	15	Eunomia	190	Ismene	2	Pallas	144	Vibilia
tha	31	Euphrosyne	183	Istria	55	Pandora	12	Victoria
nhild	52	Europa	127	Johanna	70	Panopæa	50	Virginia
lis	75	Eurydice	139	Juewa	11	Parthenope	156	Xanthippe
liope	195	Eurykleia	89	Julia	118	Peitho	169	Zelia

Annals of the Astronomical Observatory of Harvard College. . xi, Part I, Photometric Observations made principally with equatorial telescope of fifteen inches aperture during the years 7–79, by EDWARD C. PICKERING, Director, aided by Arthur rle and Winslow Upton, Assistants in the Observatory. 189 4to. Cambridge, 1879 (University Press: John Wilson &).—The subject of Photometry is that to which the large equa- al of the Harvard Observatory has been devoted since the sum- of 1877. The observations necessitated the invention and con- ction of a new class of instruments, which are described he first chapter of the volume. Chapter II is devoted to

the journal containing the photometric observations made from August, 1877, to September, 1878, and in part those of October, 1878, to March, 1879; these are numbered from 1 to 5037. Chapter III contains the reduction of the observations of Saturn and Mars, and of Jupiter and Venus at their conjunctions in 1877; and chapter IV contains the discussion of the observations made on the more conspicuous double stars visible in the latitude of Cambridge. This work is one of especial importance because it is the first time that so large an instrument has been entirely devoted to Photometry.

IV. Miscellaneous Scientific Intelligence.

1. *Geological Survey of the Public Domain.*—In volume xvii of this Journal, at page 78 (January number, 1879), the Report of the Committee of the National Academy of Sciences "appointed to consider the Scientific Surveys of the United States" which had been required of the Academy by an act of Congress, is published at length. The Report recommended two distinct departments with reference to such surveys, under separate heads—one for Surveys of Mensuration (to include the Coast and Geodetic surveys, and the topograpical work of the Land Survey office, and the other, for "the determination of all questions relating to the Geological structure and Natural Resources of the Public Domain."

With regard to the latter the report says, "in view, especially of the value of such surveys to the Land Office:"—

"The best interests of the Public Domain require, for the purposes of intelligent administration, a thorough knowledge of its geological structure, natural resources and products. The domain embraces vast mineral wealth in its soils, metals, salines, stones, clays, etc. To meet the requirements of existing laws in the disposition of the agricultural, mineral, pastoral, timber, desert and swamp lands, a thorough investigation and classification of the acreage of the Public Domain is imperatively demanded. The Committee therefore recommend that Congress establish, under the Department of the Interior, an independent organization, to be known as the United States Geological Survey, to be charged with the study of the geological structure and economic resources of the Public Domain; such a survey to be placed under a Director, who shall be appointed by the President, and who shall report directly to the Secretary of the Interior."

The Report, having been submitted to Congress, was favorably acted upon on March 3d, as regards the second of the two departments recommended in the Report; and, as the passage of the bill is an important event in the history of American scientific surveys, the portion of the Act "making appropriations to Sundry Civil Expenses," which has reference to it, is here cited (pp. 20, 21).

"For the salary of the Director of the Geological Survey, which office is hereby established, under the Interior Department, who shall be appointed by the President by and with the advice and consent of the Senate, six thousand dollars: *Provided*, That this

officer shall have the direction of the Geological Survey, and the classification of the public lands and examination of the Geological Structure, mineral resources and products of the National Domain. And that the Director and members of the Geological Survey shall have no personal or private interests in the lands or mineral wealth of the region under survey, and shall execute no surveys or examinations for private parties or corporations; and the Geological and Geographical Survey of the Territories, and the Geographical and Geological Survey of the Rocky Mountain Region, under the Department of the Interior, and the Geographical Surveys West of the One hundredth Meridian, under the War Department, are hereby discontinued, to take effect on the thirtieth day of June, eighteen hundred and seventy-nine. And all collections of rocks, minerals, soils, fossils, and objects of natural history, archæology, and ethnology, made by the Coast and Interior Survey, the Geological Survey, or by any other parties for the Government of the United States, when no longer needed for investigations in progress, shall be deposited in the National Museum.

"For the expenses of the Geological Survey and the classification of the public lands and examination of the Geological structure; mineral resources and products of the National Domain, to be expended under the direction of the Secretary of the Interior, one hundred thousand dollars;

"For the expense of a commission on the codification of existing laws relating to the survey and disposition of the Public Domain, and for other purposes, twenty thousand dollars;

"*Provided*, That the Commission shall consist of the Commissioner of the General Land Office, the Director of the United States Geological Survey, and three civilians, to be appointed by the President, who shall receive a per diem compensation of ten dollars for each day while actually engaged, and their traveling expenses; and neither the Commissioner of the General Land Office nor the Director of the United States Geological Survey, shall receive other compensation for their services upon said commission than their salaries, respectively, except their traveling expenses, while engaged on said duties; and it shall be the duty of this commission to report to Congress within one year from the time of its organization; first, a codification of the present laws relating to the survey and disposition of the public domain; second, a system and standard of classification of public lands; as arable, irrigable, timber, pasturage, swamp, coal, mineral lands and such other classes as may be deemed proper, having due regard to humidity of climate, supply of water for irrigation, and other physical characteristics; third, a system of land parcelling surveys adapted to the economic uses of the several classes of lands; and, fourth, such recommendations as they may deem wise in relation to the best method of disposing of the public lands of the western portion of the United States to actual settlers.

"The publications of the Geological Survey shall consist of the

annual report of operations, geological and economic maps illustrating the resources and classification of the lands, and reports upon general and economic geology and paleontology. The annual report of operations of the Geological Survey shall accompany the annual report of the Secretary of the Interior. All special memoirs and reports of said survey shall be issued in uniform quarto series if deemed necessary by the Director, but otherwise in ordinary octavos. Three thousand copies of each shall be published for scientific exchanges and for sale at the price of publication; and all literary and cartographic materials, received in exchange shall be the property of the United States and form a part of the library of organization: and the money resulting from the sale of such publications shall be covered into the Treasury of the United States, under the direction of the Secretary of the Interior; one hundred thousand dollars;

"For the preparation of reports, maps, and such other illustrations as may be necessary for completing the office work of the Geological and Geographical Survey of the Territories, twenty thousand dollars; to be immediately available.

"For the completion of the reports of the Geographical and Geological Survey of the Rocky Mountain Region with the necessary maps and illustrations, twenty thousand dollars; to be immediately available.

"For the preparation of reports, maps and such other illustrations as may be necessary for completing the office work of the Geographical Surveys West of the One hundredth Meridian, under the direction of the Secretary of War, twenty thousand dollars; to be immediately available."

The office of Director of the Geological Survey, "to have the direction of the Geological Survey, and the classification of the public lands, and examination of the geological structure, mineral resources and products of the *National Domain*," was thus established; and soon after, the position of Director of the Survey was given to Mr. Clarence King, who by long work in the field had already become well acquainted geologically with much of the National Domain over which his surveys were to extend.

The failure of Congress to act favorably with reference to the establishment of "Mensuration Surveys," recommended in the Report of the Committee of the Academy, is thought to be a deferring of the subject for the time, and not a rejection of the scheme.

Another move with regard to the department of the Geological Survey has been made since Mr. King received his appointment, and one which has not yet been laid before a Committee of the National Academy, and has not even been presented for public discussion, although it bears on the political and industrial interests of the country, as well as on the status of Science under the General Government.

The session of Congress, in which the Department of the Geological Survey of the Public Domain was established, was followed

by an extra session which closed on the 1st of July. The Congressional Record of the 29th of June reports that a resolution was introduced into the House of Representatives, adding after the words "National Domain" in the first paragraph of the former bill, the three words "and the States." (See the eighth line in this paragraph, on page 493). It says, further, that the resolution was discussed at length, and that, finally, an amendment passed the House, substituting, for the three words, the following—to be introduced at the same place: "and he may extend his examinations into the States." The resolution failed of being brought before the Senate for want of time.

With the words "and the States" inserted, the area geologically and economically under the Director's supervision becomes suddenly enlarged to the dimensions of the whole country from the Atlantic to the Pacific. The geological surveys of all the several States come under the control, and their prosecution is made the duty, of the General Government; and the work of exploring their mining and other resources, is also assumed by this new United States department. And this is the view which the Director takes of the amendment adopted by the House; for he personally informed the writer after the adjournment of Congress, that it was his purpose, under the act, to send a party into New England next spring.

Having been a member of the National Academy, the writer has felt it a duty here to state, that this proposed expansion of the field of work under the "Director of the Geological Survey" is wholly foreign to the views expressed in the Report of the Committee, and to the opinions brought out in their discussions. Moreover, it is entirely at variance with the objects set before the Committee by the Act of Congress requiring its appointment: this act asking that the members "take under consideration the methods and expenses of conducting all surveys of a scientific character under the War or Interior Department and the surveys of the Land Office, and to report to Congress, as soon thereafter as may be practicable, a plan for surveying and mapping the Territories of the United States on such general system as will, in their judgment, secure the best results at the least possible cost." The plan set forth by the Committee, besides having direct reference to the Territories, had in view that economy of expenditure, suggested in the act of Congress; while the new scheme, with the proposed enlargement of its scope, would involve—as State geological surveys have shown—millions of outlay for the strictly geological part, and indefinite millions besides for the economical branch—the study of "the mineral resources and products of the National Domain" "*and the States.*"

The writer is not informed as to the character of the discussion over the proposed amendment in the House of Representatives. But it seems to be plain, from the change of wording, that the meaning intended to be conveyed by it was that the Director "may extend his examinations into States" *which adjoin the*

Territories. There is an evident absurdity in an expression which adds the States—nearly the whole country—to the Territories. Had the general survey of the United States been intended by the House, the idea would have been brought out by the simple substitution of the words United States for "National Domain."

A change so great in the administration of the affairs of the Government should have a full discussion before it is accepted. It will appear to many that the Constitution has left to the States the making of their own geological surveys and the study of their own economical resources—as past history seems to attest—and that such an infringement on State rights and assumption of State responsibilities would be politically wrong; and also, that investigations into the mineral resources of the States, whether of a mine or of a granite quarry, would be followed by other evils through encroachments on private rights, and the temptations to favor private enterprises. The General Government, unlike many in foreign lands, has no ownership in the mines of California or of any other of the States, and hence has no need to establish a Mining Bureau for the country at large.

The States, for the most part, have carried forward geological surveys. The great need, previous to undertaking new surveys, in order that they may be correct and complete, is, for each, an accurate topographical survey. Before New England, or any part of this or of the other sections of the Union, has again its corps of geological surveyors, it should have in the field, for a number of years, corps of geodetic and topographical surveyors,—preparing maps in which roads, rivers, hills, mountains, State-lines, county-lines, town-lines, and all positions, are correctly given.

Within four years a scheme for the scientific survey of Connecticut has been brought before the legislature of the State by a committee which included the writer among its members. And this committee urged, in its petition, that, *first*, a topographical survey should be made in order that a satisfactory geological survey might be a possibility. It was manifest that without such a preparation the work would be half a waste of expenditure, and have to be done over again.

Topographical surveys are needed in every State as well as Territory; and for this purpose there is manifestly required the establishment of a Department of "Mensuration Surveys," under the General Government, whose geodetic work over the breadth of the country shall, in accordance with some well devised plan, be supplemented by topographical work at the expense, and under the united supervision, of the State and General Government. This done, the States could easily carry forward their own scientific and economical surveys. JAMES D. DANA.

2. *Chemical Denudation in relation to Geological Time*; by T. MELLARD READE. 62 pp. 8vo. London, 1879. (David Bogue.)—Mr. T. Mellard Reade gives, in his memoir, the results of his comparisons of the amount of denudation in various regions over

the globe, and of various considerations derived from the constitution of the earth's crust, the composition of river and sea waters and deep-sea and shallow-sea formations. He closes his volume with the conclusion that the minimum amount of time required to make the world's limestone strata is "in round numbers say 600,000,000 years;" and that this time is divided about equally between (1) the Silurian and Pre-silurian; (2) the rest of the Paleozoic ages and Triassic; and (3) the remainder of geological time. After all, this question of time geological science knows little about, beyond the general fact of its almost indefinite length.

3. *Report No. 2, of the Princeton Scientific Expedition of 1877: Topographic, Hypsometric and Meteorologic Report*, by W. LIBBEY, Jr., and W. W. MCDONALD. 56 pp. 8vo, with an Appendix of 28 pp. New York, 1879.—This Report contains geological as well as topographic information respecting the region visited by the Princeton Expedition, and has many beautiful "artotype" plates representing scenes in the mountain regions remarkable as illustrations of erosion and other geological phenomena. The height determined by the Expedition for Pike's Peak was 14,147·28 feet (made 14,146·56 by Hayden's expedition); for Mount Lincoln 14,297·80 (14,297·00 Hayden); for Mount Silverheels 13,861 (13,897 Hayden); for Mount Princeton 14,208·90 (14,196 Hayden, 14,041 Wheeler's Expedition); for Mount Evans 14,353·30 (14,340 Hayden); Mount Gray 14,363·30 (14,341 Hayden); Mount Bross, 14,255 feet; Mount Alma, 10,364·50 (10,254 Wheeler's Expedition).

4. *Lectures and Essays by the late William K. Clifford, F.R.S.*, edited by LESLIE STEPHEN and FREDERICK POLLOCK; with an introduction by F. Pollock. In two volumes, 8vo. London, 1879. (Macmillan & Co.).—The sketch, which opens this work, was written by a personal friend of the late Professor Clifford, and hence one well able to speak of him. While not attempting to be a complete biography, it brings out clearly the prominent points in the mental character and the attainments of the gifted mathematician, whose work was so suddenly interrupted. The lectures and essays contained in these two volumes are for the most part of a philosophical rather than a strictly scientific character, and hence it lies outside of the province of this Journal to give an extended notice of them. They are characterized by the clear and vigorous thought which was shown in all the work of their author. It is well both for his sake and for that of the public that they have been preserved and presented in this form.

5. *Seeing and Thinking;* by the late WILLIAM K. CLIFFORD, F.R.S. 156 pp. 8vo. London. (Nature Series: Macmillan & Co.).—Four lectures delivered by Professor Clifford at Shoreditch; they bear the titles: the Eye and the Brain; the Eye and seeing; the Brain and thinking; of Boundaries in general. They contain many important scientific facts presented in so simple a manner and with such fullness of illustration as to be intelligible even to those who have had no scientific training.

6. *The Mound Builders; Archæology of Butler County, Ohio;* by J. P. MacLean. 234 pp. 8vo, illustrated with over 100 figures. Cincinnati. (Robert Clarke & Co.)—Two-thirds of this volume are devoted to the general subject of the mound builders, and give a well digested account of the observations and results hitherto obtained. The remainder is devoted to an account of the ancient earth-works and Indian relics of Butler County, in southwestern Ohio, a region containing more of such earth-works than any other county in the State; their number is seventeen, and one of them covers an area of 95 acres. Many figures are given representing stone arrow-heads, implements and ornaments, and also plans of the earth-works, besides an Archæological map of the county.

7. *Maps of the U. S. Geological and Geographical Survey of the Territories,* F. V. Hayden, Geologist-in-Charge.—Five maps of this Survey have recently been issued, 20 to 26 by 36 inches in size, illustrating the topography and geography of portions of Utah, Idaho and Wyoming territories, and they are remarkable for beauty of execution, while of great interest for the region they illustrate. The Primary triangulation in the survey was carried forward by A. D. Wilson, and the topography by H. Gannett, G. B. Chittenden, G. R. Bechler and F. A. Clark. These maps include a drainage map, a map of the Yellowstone National Park on a scale of two miles to an inch, and maps of other portions of the Territories named, giving the altitudes of numerous measured peaks, and by means of contour lines, the character of the various mountain ranges and plateaus, including the Wind River Mountains, the Bear River Range, the Teton Range, the Snake River Range, and others. The engraving is by J. Bien.

Notices of the following new works are deferred to another number:

Report on the Geology of the Henry Mountains, by G. K. Gilbert. 160 pp. 4to. U. S. Geographical and Geological Survey of the Rocky Mountain Region, J. W. Powell, in charge. Department of the Interior.

Pennsylvania Second Geological Survey. Harrisburg, 1879. (1.) Second Report of Progress in the Laboratory of the Survey at Harrisburgh, by Andrew S. McCreath. 438 pp. 8vo.—(2.) Report, Part first, on the Northern townships of Butler County; Part second, on a Special Survey along the Beaver and Shenango Rivers, by H. Martyn Chance. 248 pp. 8vo, with 6 maps, 1 profile section and 154 vertical sections.

A Manual of Palæontology for the use of students, with a general introduction on the principles of Palæontology, by Henry Allyn Nicholson, Prof. Nat. Hist. Univ. St. Andrews. Second edition, revised and greatly enlarged. 2 volumes, with numerous illustrations. 1879, Edinburgh and London. (Wm. Blackman & Sons.)

Geological Survey of Alabama, Report of Progress for 1877, 1878, by Eugene A. Smith, Ph.D., State Geologist. 140 pp. 8vo. Montgomery, Alabama, 1879.

Solar Light and Heat: the Source and the Supply. Gravitation with explanation of Planetary and Molecular Forces, by Zachariah Allen, LL.D. 241 pp. 8vo. New York, 1879. (D. Appleton & Co.)

OBITUARY.

James Clerk Maxwell, F.R.S.—By the early death of Professor Maxwell in his forty-ninth year the University of Cambridge has sustained a loss which will be felt as personal by all students of physical science. He entered perhaps more thoroughly than any of his contemporaries into the splendid inheritance of scientific speculation left behind by Faraday, and though he has made invaluable additions to that inheritance, the world must ever regret that to one so gifted the time should have been denied for attaining the great results which seem, as we read his papers, to have been so nearly within his grasp.

James Clerk Maxwell, scholar of Trinity College, Cambridge, took his degree as Second Wrangler in the Mathematical Tripos of 1854. He became a fellow of his college in 1855, and accepted the chair of Physics in the Marischal College, Aberdeen, in 1856, which he held until the amalgamation of the College with King's College. In 1860 he was elected Professor of Physics in King's College, London, where he remained till 1865. But he was not in his element as a lecturer, and it was not until his appointment in 1871 to the professorship of Experimental Physics in Cambridge, with the direction of the laboratory which the munificence of the Duke of Devonshire shortly afterwards presented to the University, that he found himself in a position thoroughly suited to his tastes and abilities.

His chief contributions to the progress of science are to be found in the numerous series of his papers. Among the earlier of these are several discussions of great interest regarding the action of colors on the retina, with especial reference to the phenomena of color blindness. His classical paper on Saturn's rings was published in the Astronomical Society's Notices for 1859. In this he proved that the theory of the solidity of the rings is untenable, and that they probably consist of an almost continuous congeries of meteorites. He also had a share in the determination of one of the most important scientific measurements that have been made in recent times, the formation, namely, of the standard known as the British Association Unit of Electrical Resistance, an account of which appears in the British Association Report for 1864.

But the subject which had most attraction for him was the inquiry into the ultimate constitution of matter and the mechanism which produces the phenomena of force, whether electrical or gravitational. Masterly expositions by him of the dynamical theory of gases are to be found in the British Association Report for 1859, the Philosophical Magazine for 1860, the Philosophical Transactions for 1867, the article on "Atoms" of the new Encyclopædia Britannica, and in his only too concise and pregnant Theory of Heat. It is, however, with his attempts at a mechanical theory of electricity, magnetism and light that his name will

be, in all probability, most closely associated in future. He thoroughly endorsed Faraday's rejection of the theory of electrical action at a distance, and sought, with him, to explain all electrical and magnetic phenomena as the results of local strains and motions in a medium whose contiguous parts only act on one another by pressure and tension. Though many of Maxwell's results are contained in his great Treatise on Electricity and Magnetism, the student will not willingly pass over his papers on Molecular Vortices, in vols. xxi and xxiii of the Philosophical Magazine, or his Dynamical Theory of the Electromagnetic Field, in the Proceedings of the Royal Society in 1864. Such luminous imagination together with originality of conception is shown in these speculations that the reader feels Professor Maxwell's genius no less in his own inability to follow them out to their conclusion than in his certainty that the guide we have lost could have knit them together into a magnificent induction if only the full term of life had been allotted to him.

This is the regret that the world of science at large feels. Those only whose privilege it was to study under Professor Maxwell's direction can rightly estimate that genial kindness and sympathy which, no less than his genuine enthusiasm, so inspirited them that they know not whether they labored more from love for their science or from regard for their master.—*Athenæum, Nov.* 15.

APPENDIX.

Art. LIX.—*Notice of New Jurassic Reptiles;* by Professor O. C. Marsh. With Plate III.

Numerous remains of Reptiles from the Jurassic deposits of the Rocky Mountains have recently been received at the Yale Museum, and some of the more interesting Dinosaurs are here briefly described. These pertain to several distinct groups, and throw considerable light on the forms already described from the same horizon.*

Camptonotus dispar, gen. et sp. nov.

The present genus is most nearly allied to *Laosaurus*, but differs in several points. The cervical vertebræ are all opisthocœlous, while those known in *Laosaurus* are nearly plane. The pubis, moreover, is broad and thin in front of the acetabulum, and directed well forward. It has a deep, well marked articular face for the support of the femur. The ischium is expanded at its distal end, and has an extensive surface for union with its fellow. The femur is longer than the tibia.

This genus agrees with *Laosaurus* in one important character, namely, the sacral vertebræ are not coössified. That this is not merely a character of immaturity is shown by some of the other vertebræ in the type specimen, which have their neural arches so completely united to the centra that the suture is nearly or quite obliterated. To this character of the sacral vertebræ, the name of the present genus refers. With *Laosaurus*, this genus forms a distinct family, which may be called *Laosauridæ*.

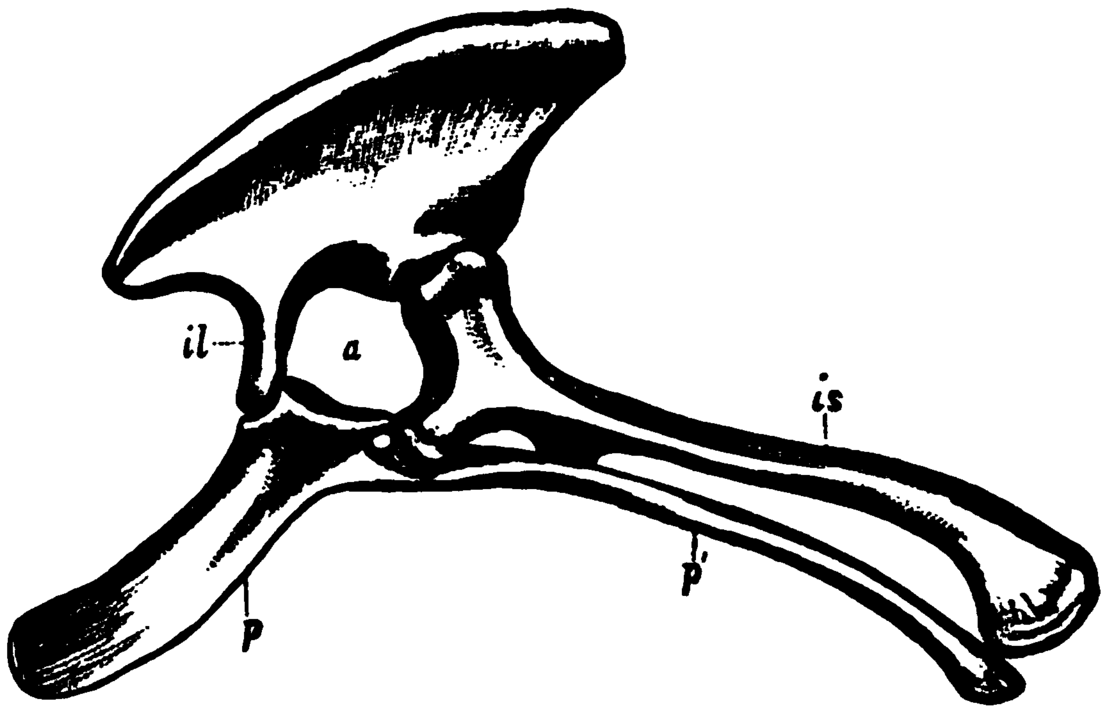
The teeth in *Camptonotus* resemble those of *Laosaurus*, and are in a single row in close-set sockets. The rami of the lower jaws were united in front only by cartilage. There are nine cervical vertebræ, all of which bear short ribs, as in the Crocodiles. The dorsal vertebræ have their articular faces nearly plane. The sacral vertebræ in all the known specimens are separate, and their transverse processes are each supported by two centra. (Plate III, figure 3). The chevrons have their articular faces joined together.

The fore limb is much reduced in size. There are five digits in the manus, supported by nine carpal bones, three of which are united in one on the radial side. The number of phalanges, beginning with the first digit, was 2, 3, 3, 3, 2. The

* This Journal, vol. xvi, p. 411; and vol. xvii, pp. 85 and 181.

form and proportions of the various elements of the fore limb are shown in Plate III, figure 1.

The pelvic arch is quite unlike any hitherto described. In its general form the ilium resembles that of *Morosaurus*, but the proportions are reversed. The massive portion in the present genus is not in front, but behind, as the ischium is larger than the pubis. The relative position and form of the elements of the pelvic arch are shown in the figure below.



Pelvic arch of *Camptonotus dispar*, Marsh; side view, one twelfth natural size. *a.* acetabulum; *il.* ilium; *is.* ischium; *p.* pubis; *p'.* postpubis.

The femur has a long pendant third trochanter, and a prominent ridge to play between the tibia and fibula. The tibia is stout, and somewhat shorter than the femur. The fibula is slender, and shorter than the tibia. The astragalus and calcaneum are distinct. The second row of tarsals contains but two bones. The first digit in the pes was rudimentary, and did not reach the ground. The second, third and fourth were well developed. The fifth was entirely wanting. The number of phalanges, beginning with the first digit, was 2, 3, 4, 5. The structure of the hind limb and foot is well shown in Plate III, figure 2, which is taken from the same skeleton as figure 1.

Some of the principal measurements of the present species are as follows:

United length of the nine cervical vertebræ	565·mm
Length of axis	54·
Transverse diameter of posterior articular face	41·
Length of ninth cervical vertebra	64.
Transverse diameter of posterior articular face	63·
Length of humerus	337·
Length of radius	245·
Length of ulna	260·
Length of femur	565·
Length of tibia	555·

The known remains of this species indicate an animal about eight or ten feet in height, and herbivorous in habit. All the specimens discovered are from the Atlantosaurus beds of the Upper Jurassic.

Camptonotus amplus, sp. nov.

A second species of this genus, about three times as large as the one just described, is represented by various remains, among which is a left hind foot nearly entire. There were three functional digits in this foot, the first being rudimentary, and the fifth entirely wanting. The metatarsal of the first digit is a splint, much curved, and with the apex above. The terminal phalanx of this digit is much compressed, not round as in the smaller species. The second metatarsal is of much greater length. The terminal phalanx of this digit is longer in proportion than that of the preceding species. The third and fourth digits were large and powerful. The main dimensions of this foot are as follows:

Length of second metatarsal	295·mm
Greatest diameter of proximal end	113·
Length of third metatarsal	345·
Greatest diameter of proximal end	150·
Transverse diameter of distal end	102·
Length of fourth metatarsal	305·
Length of first phalanx of third digit	140·
Length of first phalanx of second digit	120·

The remains of the present species are from a lower horizon in the Jurassic than those described above, but within the limits of the Atlantosaurus beds.

Brontosaurus excelsus, gen. et sp. nov.

One of the largest reptiles yet discovered has been recently brought to light, and a portion of the remains are now in the Yale collection. This monster apparently belongs in the *Sauropoda*, but differs from any of the known genera in the sacrum, which is composed of five thoroughly coössified vertebræ. In some other respects it resembles *Morosaurus*. The ilium is of that type, and could hardly be distinguished from that of *M. robustus*, excepting by its larger size. One striking peculiarity of the sacrum in the present genus is its comparative lightness, owing to the extensive cavities in the vertebræ, the walls of which are very thin.

The lumbar vertebræ have their centra constricted, and also contain large cavities. The caudals are nearly or quite solid. The chevrons have their articular heads separate. The sacrum of this animal is, approximately, 50 inches ($1·27^{m}$) in length. The last sacral vertebra is 292^{mm} in length, and 330^{mm} in transverse diameter across the articular face.

A detailed description of these remains will be given in a subsequent communication. They are from the Atlantosaurus beds of Wyoming. The animal was probably seventy or eighty feet in length.

Stegosaurus ungulatus, sp. nov.

Additional specimens of *Stegosaurus* have been recently secured from several localities, and much new information in regard to the group has thus been obtained. These reptiles belong to the Dinosauria, but differ widely from any of the known suborders. The most striking character, to which the name refers, is the huge dermal plates which protected the animal. A number of these, from two to three feet in diameter, and others of smaller size, were found with the remains of the present species.

The skull is very small, and more lacertilian than in the typical Dinosaurs. The brain cavity is remarkably small.

The vertebræ known are all solid, and have nearly plane or slightly concave articular extremities. The fore limbs are shorter than those behind. In the present species, the humerus is very short, and the ulna has a very large olecranon process. The terminal phalanges preserved are short, broad, and obtuse, as in some ungulate mammals. The femur is long, entirely without a third trochanter, and the ridge between the tibia and fibula is only faintly indicated. The tibia is of moderate length, and the astragalus is firmly coössified with it. The fibula is slender, and united firmly with the calcaneum and lower end of the tibia. The present species may prove to be generically distinct from the type species, *Stegosaurus armatus*,* described by the writer from a different locality.

In one specimen of the present species, some of the more important dimensions are as follows:

Transverse diameter of occipital condyle	44·mm
Vertical diameter	25·
Transverse diameter of foramen magnum	31·
Greatest transverse diameter of brain cavity	33·
Length of third cervical vertebra	85·
Length of humerus	590·
Length of tibia with astragalus	750·
Length of terminal phalanx	85·
Greatest width	70·

Cœlurus fragilis, gen. et sp. nov.

A very small reptile, apparently a Dinosaur, left its remains in the same locality with *Camptonotus dispar*. The most characteristic specimens obtained are vertebræ, which in the dorsal and lumbar region have their centra so much excavated that

* This Journal, vol. xiv, p. 513, Dec., 1877.

the walls are reduced to a thin shell. There are apparently no partitions across their cavity, and the inner surface of the walls is quite smooth. The anterior caudal vertebræ, at least, have essentially the same character. The trunk vertebræ preserved are elongate, biconcave, with high neural arches, united to the centra by suture. The sides of the vertebræ are somewhat excavated, and the openings into the cavity are all small. The cup at each end of the centra is unusually smooth, and regular. The zygapophyses are near together, and stand nearly vertical.

The following measurements will indicate the size of this animal:

Length of centrum of lumbar vertebra	35·mm
Transverse diameter of anterior face of centrum	19·
Vertical diameter	21·
Least transverse diameter of centrum	10·
Least thickness of walls of centrum	1·
Length of anterior caudal	33·
Transverse diameter of anterior face	17·
Thickness of walls of centrum, near middle	1·
Least transverse diameter of centrum	10·

The known remains of this species indicate an animal about as large as a wolf, and probably carnivorous.

Yale College, New Haven, November 18, 1879.

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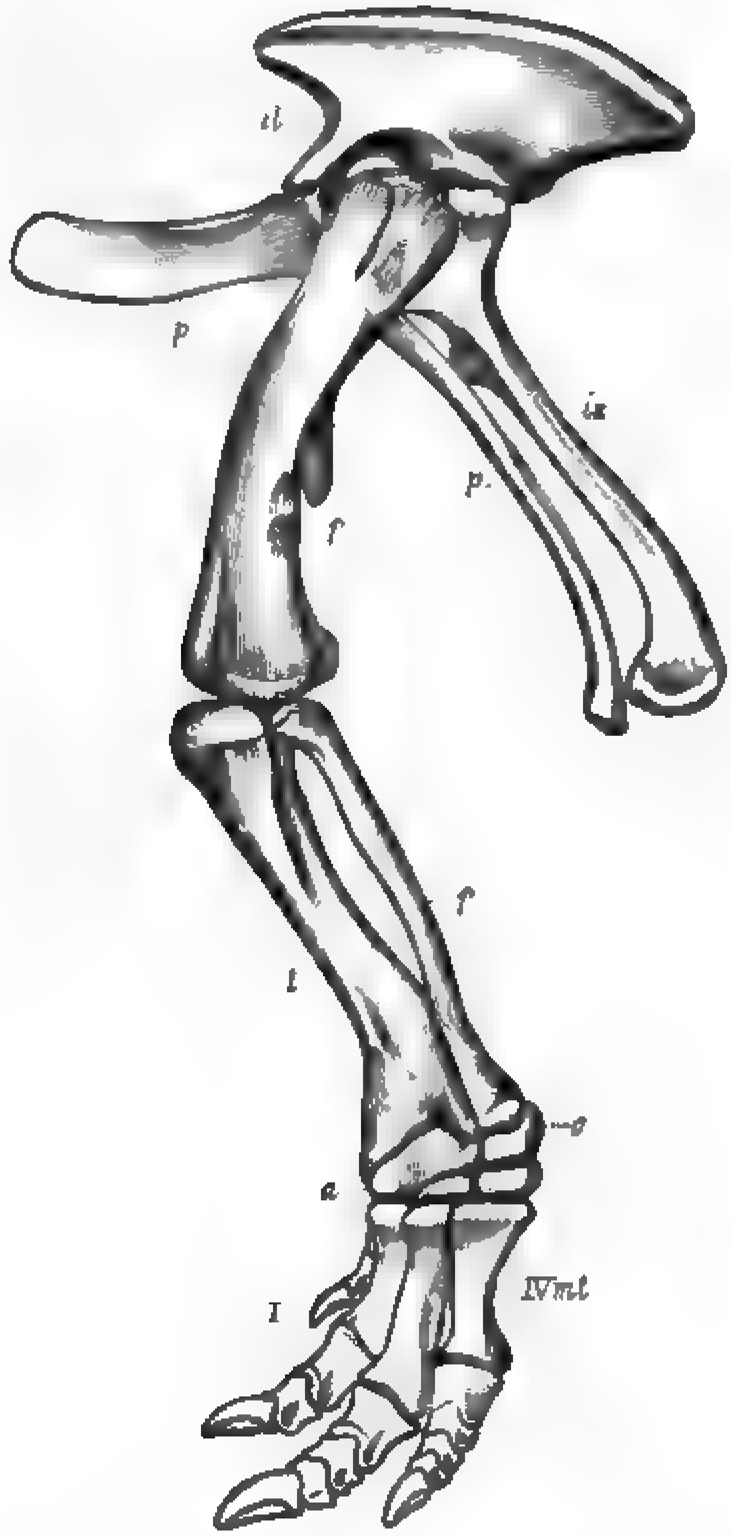

Figure 1.—Bones of left fore leg of *Camptonotus dispar*, Marsh; *s.* scapula; *c.* coracoid; *h.* humerus; *r.* radius; *u.* ulna; I. first digit; V fifth digit.

Figure 2.—Bones of left hind leg of *Camptonotus dispar*; *il.* ilium; *is.* ischium; *p.* pubis, *p'.* post-pubis; *f.* femur; *t.* tibia; *f.'* fibula; *a* astragalus; *c.* calcaneum; I. first metatarsal, IV*mt.* fourth metatarsal. Both figures one twelfth natural size.

Figure 3.—Sacral vertebra of same individual, seen from the left. *a* anterior face for transverse process; *b.* posterior face.

Figure 4.—The same vertebra, front view. Both one sixth natural size.

INDEX TO VOLUME XVIII.*

* The Index contains the general heads BOTANY, GEOLOGY, MINERALOGY, ZOOLOGY, and under each the titles of Articles referring thereto are mentioned.

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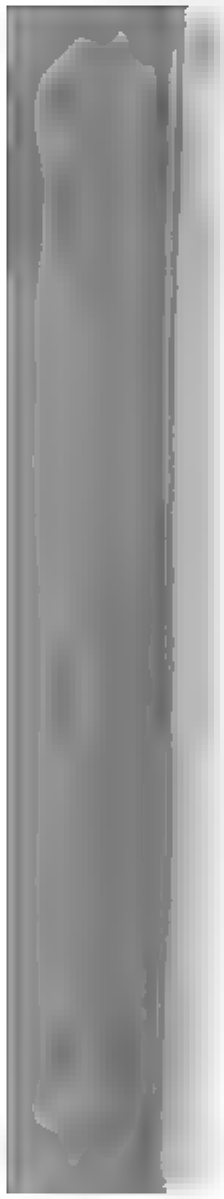

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